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JOURNAL OF THE

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JOURNAL OF THE

BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XIII JUNE, 1926 Number 6

OLD AND NEW IDEAS OF CONTROL OF STRENGTH OF CONCRETE

BY JOHN G. AHLERS *

(Presented before the Affiliated Technical Societies of Boston, April 21, 1926)

CONCRETE is not controlled in strength by proportion of cement to sand and stone, but by ratio of cement to water only. The addition of sand and stone, or gravel, only makes the concrete either more economical or less economical, depending on whether much or little is added, or depending whether the sand and stone are well or poorly graded. The results of 100,000 tests at Lewis Institute prove this statement.

Although unknown to many of us at that time, we now know that all concrete produced in the past was strong in proportion as more or less water was used with the cement, and not because of any proportions of cement to fine and coarse aggregate. It was merely because we used less water when using less aggregate that our concrete was stronger.

When we control concrete for strength by means of the water-ratio theory, we must discard our old conception that good or bad concrete depended upon fixed proportions of cement to sand and stone without regard to the amount of water used. In fact, we must consider concrete as so much water-cement paste swelled up and filled out with inert sand and stone filler grains for the sole purpose of economy.

When engineers and contractors both approach this problem they can profitably keep these two ideas separate — the engineer can confine *his* efforts and attention to that of *strength* as controlled by the water-cement ratio; and the contractor can confine *his* efforts and attention to the *grading and quality of the aggregate* so as to enable him to add as much aggregate as possible while still leaving the resulting concrete workable and plastic.

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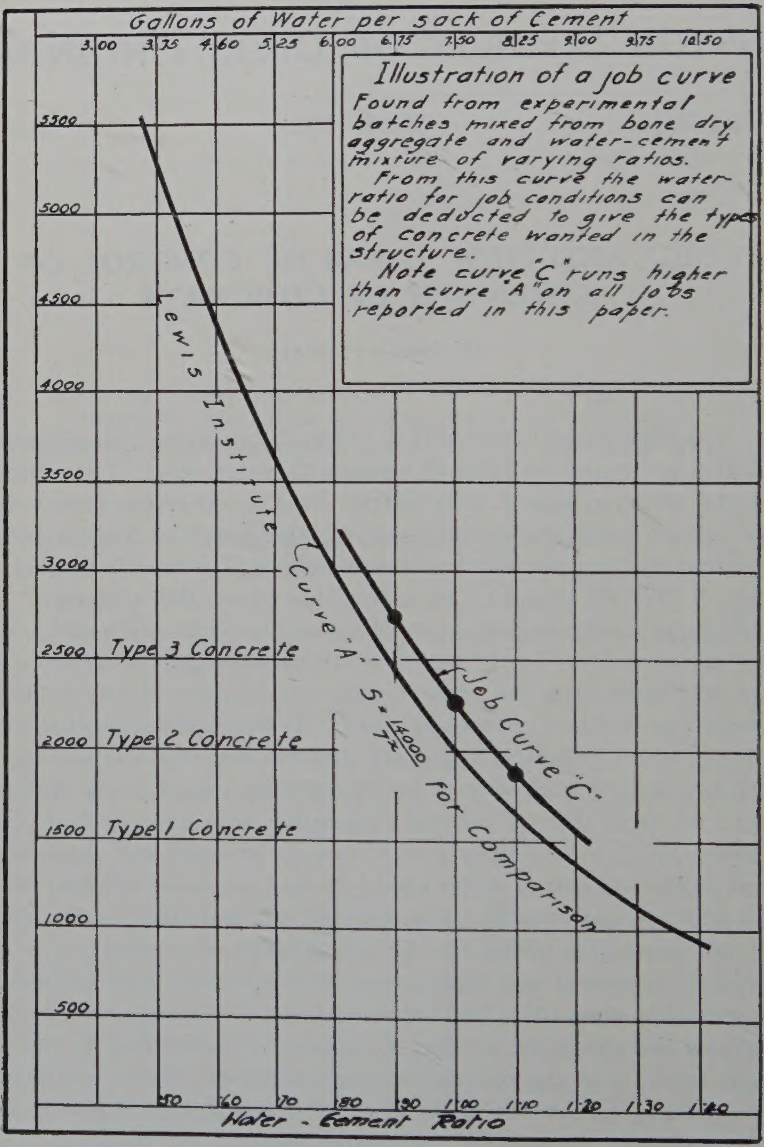


FIG. 1.—JOB CURVE DERIVED FROM EXPERIMENTAL BATCHES OF BONE-DRY AGGREGATE AND VARYING WATER-CEMENT RATIOS

It is the confusing of these two distinct and separate phases — strength and economy — that causes misunderstanding and creates opposition to the new methods developed by the Portland Cement Association and other progressive engineers. We still hear, and probably will in the future, the statement that strength of concrete is affected by a poor grading of stone or sand; and this idea must be discarded before concrete can be controlled successfully by the water-ratio method.

Grading and Quantity of Aggregate Control Economy or Yield of Concrete and Affect Yield Only, having No Connection with Strength as long as Concrete is Plastic

Contractor's Viewpoint. — The contractor will soon learn that good grading of sand and good grading of stone are essential to get a high yield in the concrete, for when the amount of water per bag of cement is fixed, there will be no other means of securing economy and high yield. The engineer should allow him to work this out for himself. There is plenty of literature and information available by which he can study and evaluate his aggregate; or he can by actual trial find the most workable plastic mix producing the greatest amount of concrete for a given amount of water and cement, by mixing different kinds of sand and stone available in various proportions and noting the results. When he reaches this stage the engineer can aid him by making a series of cylinders of the concrete that the contractor wishes to use.

The Water-Cement Ratio $\frac{W}{C}$ *Controls the Strength of Concrete and Affects Strength Only*

Engineer's Function. — The question of strength is the only one with which the engineer should be greatly concerned. Having a given job condition and method of operation, a definite grade of cement, and a certain kind of aggregate that the contractor wishes to use, the engineer can determine exactly what strength results from these for a water-cement ratio of "one." When once the so-called "job constant" is established from the water-cement ratio of "one," for the materials to be used (regardless of the quantity of sand, gravel or mix), then as long as the concrete is plastic and workable, the engineer can specify greater or lesser amounts of water which will proportionately affect the strength of concrete in accordance with the well-known laws of the water-ratio theory.

Quality of Aggregates (Cleanliness, Chemical Composition, Soundness, etc.) has the Effect of Producing Variations in Job Curves for the Same Grade of Cement and Water-Ratios

This factor which enters into the production of concrete is well known and is the one that engineers and contractors refer to as poor or good sand, and is usually tied up in their minds with the grading, but in reality has no relation thereto. In a paper, entitled "New Experiences in Concrete Control," presented before the American Concrete Institute in February, 1926, by the author of this article, the so-called "job curves" were introduced for the first time.

The factors producing any job curve are quality of aggregate and quality of cement. A job curve is plotted from the strengths of concrete specimens produced from any job operation under different water-cement ratios. Once a few points are found on this curve any desired strength may be obtained by using the corresponding ratio on the curve.

Lately I have proposed another term, — "job constant."

The job constant is the strength obtained on any job operation with a water-cement ratio of "one." This constant will vary from job to job, depending on *quality* of cement and aggregate used, method of manipulation (time of mixing), etc., but will not vary within the job itself. Once established and occasionally verified it furnishes a sound guide for uniform concrete when water-cement ratio is carefully controlled from batch to batch.

VARIABLES AFFECTING STRENGTH OF CONCRETE

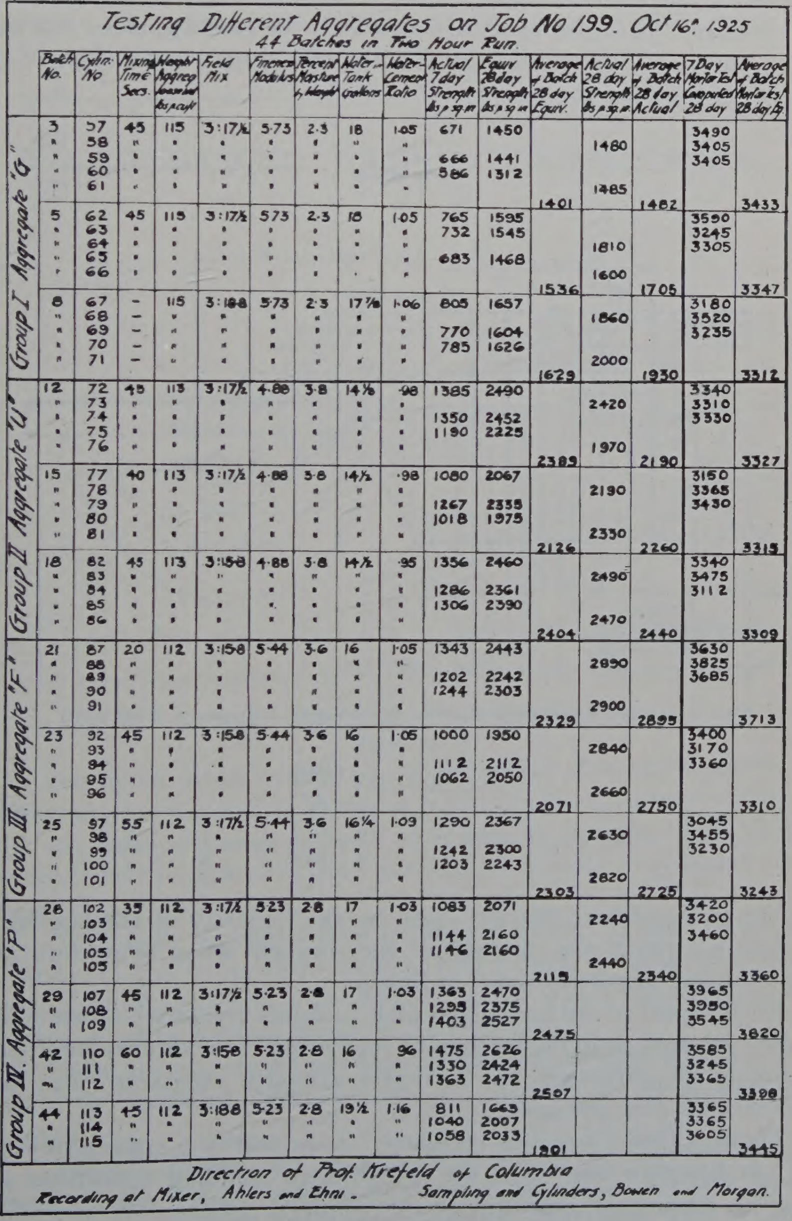
We always have the following variables to consider when making concrete: (1) quality of cement; (2) quality of aggregate; (3) quantity of aggregate; (4) quantity of water; (5) quantity of cement.

Let us see how these variables enter into our problem of economical concrete and how we can control them simply and therefore make a uniform low-cost product and help the whole industry.

First and second are the *quality of the cement and aggregate*. These two will not vary much within the job itself. They establish the above-mentioned job curve and job constant. The engineer and contractor can control them by buying "high testing" cement and clean, sharp sand and gravel or stone; but once materials are furnished to an operation they do not enter into our problem of job control.

Third is the *quantity of aggregate* and, as has been stated previously, the variation in grading and quantity does not affect the strength as

TABLE 1.



Testing Different Aggregates on Job No 199. Oct 16th 1925
44 Batches in Two Hour Run.

	Batch No.	Cylin. No	Mixing Time Secs.	Weight Aggreg. [illegible] lbs p cu ft	Field Mix	Fineness Modulus	Percent Moisture by Weight	Water—Tank Gallons	Water-Cement Ratio	Actual 7 day Strength lbs p sq in	Equiv 28 day Strength lbs p sq in	Average of Batch 28 day Equiv.	Actual 28 day Strength lbs p sq in	Average of Batch 28 day Actual	7 Day Mortar Test Computed 28 day	Average of Batch Mortar Test 28 day Eq.
Group I Aggregate "G"	3	57	45	115	3:17½	5·73	2·3	18	1·05	671	1450				3490	
	"	58	"	"	"	"	"	"	"				1480		3405	
	"	59	"	"	"	"	"	"	"	666	1441				3405	
	"	60	"	"	"	"	"	"	"	586	1312					
	"	61	"	"	"	"	"	"	"			1401	1485	1482		3433
	5	62	45	115	3:17½	5·73	2·3	18	1·05	765	1595				3590	
	"	63	"	"	"	"	"	"	"	732	1545				3245	
	"	64	"	"	"	"	"	"	"				1810		3305	
	"	65	"	"	"	"	"	"	"	683	1468					
	"	66	"	"	"	"	"	"	"			1536	1600	1705		3347
	8	67	—	115	3:18·8	5·73	2·3	17⅞	1·06	805	1657				3180	
	"	68	—	"	"	"	"	"	"				1860		3520	
	"	69	—	"	"	"	"	"	"	770	1604				3235	
	"	70	—	"	"	"	"	"	"	785	1626					
	"	71	—	"	"	"	"	"	"			1629	2000	1930		3312
Group II Aggregate "U"	12	72	45	113	3:17½	4·88	3·8	14⅛	·98	1385	2490				3340	
	"	73	"	"	"	"	"	"	"				2420		3310	
	"	74	"	"	"	"	"	"	"	1350	2452				3330	
	"	75	"	"	"	"	"	"	"	1190	2225					
	"	76	"	"	"	"	"	"	"			2389	1970	2190		3327
	15	77	40	113	3:17½	4·88	3·8	14½	·98	1080	2067				3150	
	"	78	"	"	"	"	"	"	"				2190		3365	
	"	79	"	"	"	"	"	"	"	1267	2335				3430	
	"	80	"	"	"	"	"	"	"	1018	1975					
	"	81	"	"	"	"	"	"	"			2126	2330	2260		3315
	18	82	45	113	3:15·8	4·88	3·8	14½	·95	1356	2460				3340	
	"	83	"	"	"	"	"	"	"				2490		3475	
	"	84	"	"	"	"	"	"	"	1286	2361				3112	
	"	85	"	"	"	"	"	"	"	1306	2390					
	"	86	"	"	"	"	"	"	"			2404	2470	2440		3309
Group III. Aggregate "F"	21	87	20	112	3:15·8	5·44	3·6	16	1·05	1343	2443				3630	
	"	88	"	"	"	"	"	"	"				2890		3825	
	"	89	"	"	"	"	"	"	"	1202	2242				3685	
	"	90	"	"	"	"	"	"	"	1244	2303					
	"	91	"	"	"	"	"	"	"			2329	2900	2895		3713
	23	92	45	112	3:15·8	5·44	3·6	16	1·05	1000	1950				3400	
	"	93	"	"	"	"	"	"	"				2840		3170	
	"	94	"	"	"	"	"	"	"	1112	2112				3360	
	"	95	"	"	"	"	"	"	"	1062	2050					
	"	96	"	"	"	"	"	"	"			2071	2660	2750		3310
	25	97	55	112	3:17½	5·44	3·6	16¼	1·09	1290	2367				3045	
	"	98	"	"	"	"	"	"	"				2630		3455	
	"	99	"	"	"	"	"	"	"	1242	2300				3230	
	"	100	"	"	"	"	"	"	"	1203	2243					
	"	101	"	"	"	"	"	"	"			2303	2820	2725		3243
Group IV. Aggregate "P"	28	102	35	112	3:17½	5·23	2·8	17	1·03	1083	2071				3420	
	"	103	"	"	"	"	"	"	"				2240		3200	
	"	104	"	"	"	"	"	"	"	1144	2160				3460	
	"	105	"	"	"	"	"	"	"	1146	2160					
	"	105	"	"	"	"	"	"	"			2115	2440	2340		3360
	29	107	45	112	3:17½	5·23	2·8	17	1·03	1363	2470				3965	
	"	108	"	"	"	"	"	"	"	1295	2375				3950	
	"	109	"	"	"	"	"	"	"	1403	2527	2475			3545	3820
	42	110	60	112	3:15·8	5·23	2·8	16	·96	1475	2626				3585	
	"	111	"	"	"	"	"	"	"	1330	2424				3245	
	"	112	"	"	"	"	"	"	"	1363	2472	2507			3365	3398
	44	113	45	112	3:18·8	5·23	2·8	19½	1·16	811	1663				3365	
	"	114	"	"	"	"	"	"	"	1040	2007				3365	
	"	115	"	"	"	"	"	"	"	1058	2033	1901			3605	3445

Direction of Prof. Krefeld of Columbia
Recording at Mixer, Ahlers and Ehni. Sampling and Cylinders, Bowen and Morgan.

long as the resulting concrete is workable and plastic (slump from 4 to 8 inches). The amount used per batch should, of course, be controlled and constant. It is also necessary to watch the grading, since it affects the economy of the resulting mix, although it may not influence the strength of the concrete.

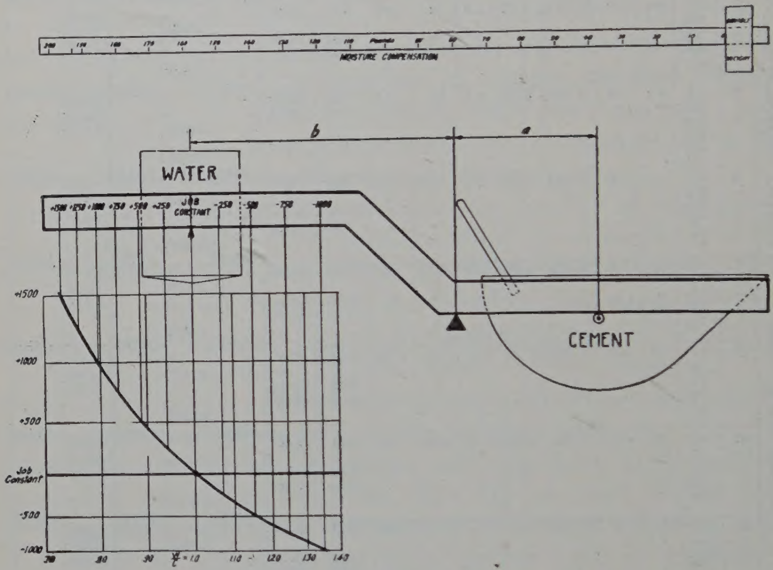


FIG. 2. — DIAGRAMMATIC SKETCH OF AHLERS CONCRETE STRENGTH REGULATOR

The curve is $S = \frac{14000}{A^x}$

$x = \frac{W}{C} = \frac{a}{b}$ by weight. For $\frac{W}{C} = 1$, $\frac{a}{b} = \frac{62.5}{94.0}$ lbs. $= \frac{2}{3}$ by weight

The *workability* is affected, also, by the quantity of the aggregate, but does not affect the strength of the concrete when kept controlled within the forementioned limits of slump.

With regard to the fourth and fifth variables (quantity of water and cement) we need a simple method of regulating these exactly and hence controlling all variables. A "concrete strength regulator" has been developed for this purpose.

The so-called "strength regulator" is in reality a contractor's job tool. It has now been used on ten different building operations and has given remarkably uniform and economical results. We would not consider getting along without it. Every batch comes out the same and is of the same strength because *all* inequalities of cement volume are automatically compensated for by the water. With the moisture in aggregate allowed for along the line of maximum average, every batch of concrete must be as strong as, or stronger than, desired.

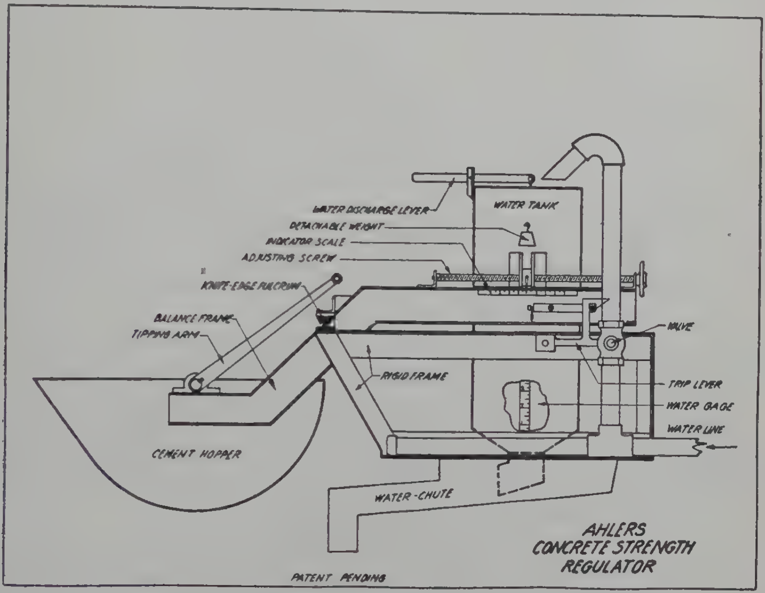


FIG. 3. — SECTIONAL VIEW OF REGULATOR

Too much stress cannot be placed on the economy resulting from uniformity of batch after batch of concrete. Each output of the mixer will have the ultimate amount of aggregate present, controlled only by workability, and this gives remarkable results in economy as facts shown later will confirm.

The fourth variable is the *quantity of water*. It may be noted, by a study of the water-ratio curves, that errors in measuring water as small as three quarts in a two-bag batch will affect the strength of concrete as much as 200 lbs. per sq. in. at 28 days.

There are two conditions that change the amount of water to each batch: (*a*) moisture in aggregate; (*b*) irregularity in measuring apparatus.

Moisture in Aggregate. — Variations due to moisture content of the aggregate are not as great as commonly assumed. Various test data attached hereto show that this variation runs from 1½ to 2½ per

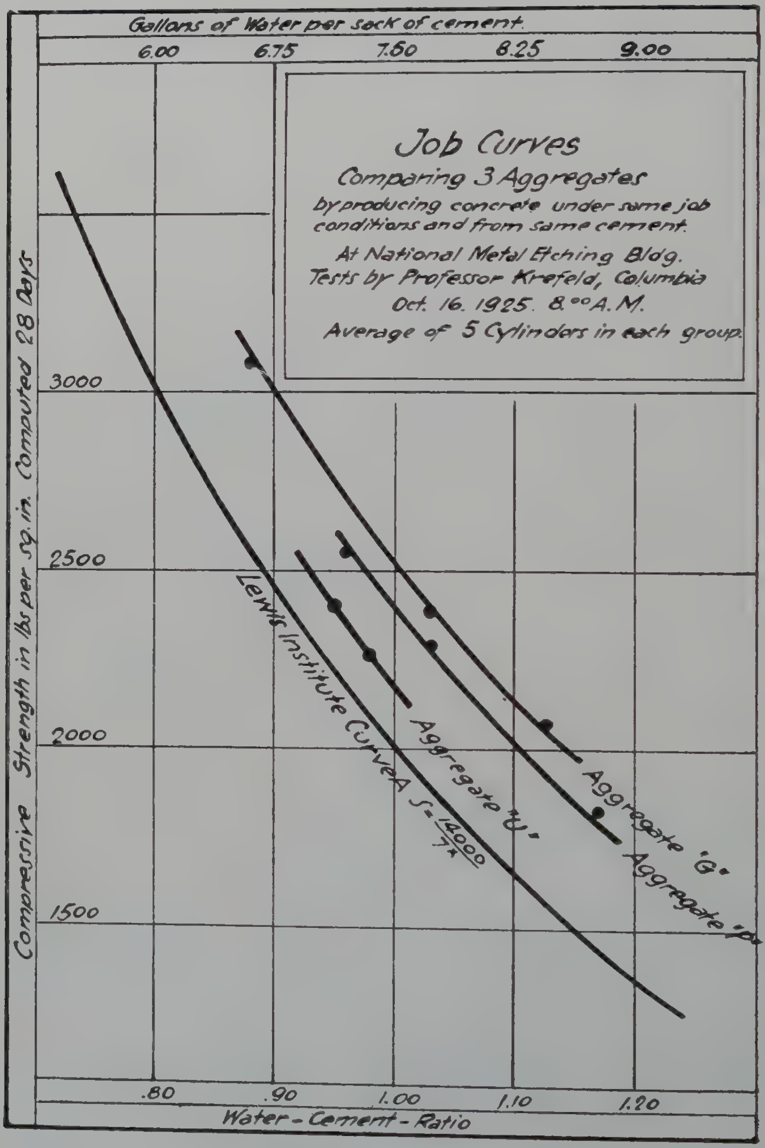


FIG. 4. — JOB CURVE COMPARING THREE AGGREGATES

Table 2. — Comparison between 7-Day and 28-Day Cylinders. Tests of October 16, 1925

Batch Number	Actual 7-Day Strengths (Lbs. per Sq. In.)	Computed 28-Day Strengths (Lbs. per Sq. In.)	Actual 28-Day Strengths (Lbs. per Sq. In.)	Per Cent Lower than Actual 28-Day Strengths	Per Cent Higher than Actual 28-Day Strengths
3	671	1,450	1,480	2.0	–
3	666	1,441	1,485	7.5	–
3	586	1,312			
5	765	1,595	1,810	15.2	–
5	732	1,545			
5	683	1,468	1,600	12.1	–
8	805	1,657	1,860	9.2	–
8	770	1,604	2,000	16.7	–
8	785	1,626			
12	1,385	2,490	2,420	–	2.8
12	1,350	2,452	1,970	–	15.7
12	1,190	2,225			
15	1,080	2,067	2,190	5.6	–
15	1,267	2,335	2,330	7.5	–
15	1,018	1,975			
18	1,356	2,460	2,490	1.2	–
18	1,286	2,361	2,470	3.8	–
18	1,306	2,390			
21	1,343	2,443	2,890	15.4	–
21	1,202	2,242	2,900	21.6	–
21	1,244	2,303			
23	1,000	1,950	2,840	31.2	–
23	1,112	2,112	2,660	21.7	–
23	1,062	2,050			
25	1,290	2,367	2,630	10.0	–
25	1,242	2,300	2,820	19.4	–
25	1,203	2,243			
28	1,083	2,071	2,240	7.6	–
28	1,144	2,160	2,440	11.5	–
28	1,146	2,160			
Average	1,059	2,028	2,276	12.0	9.2

7-day and 28-day cylinders were made out of same samplerfull. Bracketed results indicate that the average of these was used for comparison with 28-day results.

cent, or that the variation is usually not greater than half of 1 per cent.

By adopting what in the paper before the American Concrete Institute was termed a "*maximum average*" from the results of tests made on the job, we are always on the safe side, and the batches that are running drier than this assumed "*maximum average*" have a strength a little higher than anticipated. This is borne out by actual test results, as shown on attached diagrams. (Figs. 5, 6 and 7.)

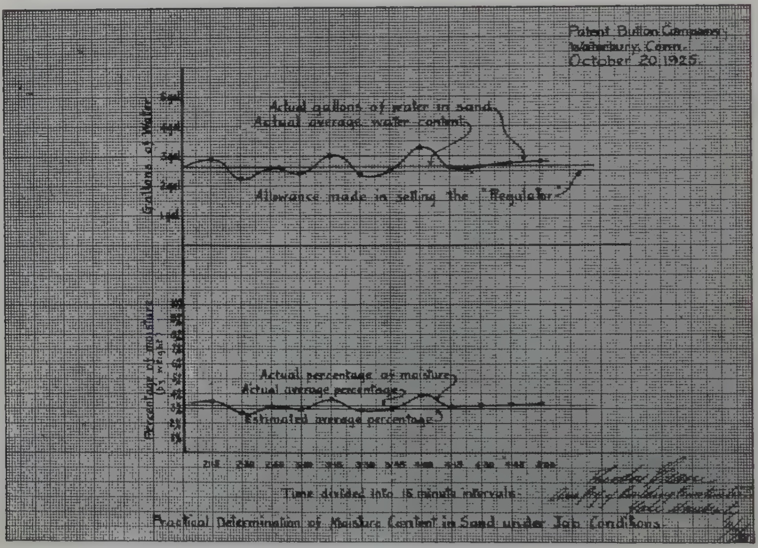


FIG. 5. — MOISTURE CONTENT OF SAND UNDER JOB CONDITIONS — PATENT BUTTON COMPANY

The amount of aggregate per batch may be varied to produce the desired workability of the concrete, provided compensation be made for the additional amount of moisture that is added or subtracted in this manner.

Irregularity in Measuring Apparatus. — Irregularities in measuring the water are well known, of common occurrence and have been ignored too much in the past. There are good appliances available for measuring water, but they are expensive and get out of order easily. The average "mixer man" is impatient and must be given an easily understood way of measuring the water. If the water can be weighed automatically in accordance with, or depending upon, the amount of cement, this is an ideal arrangement. Usually we see measuring tanks put aside, and

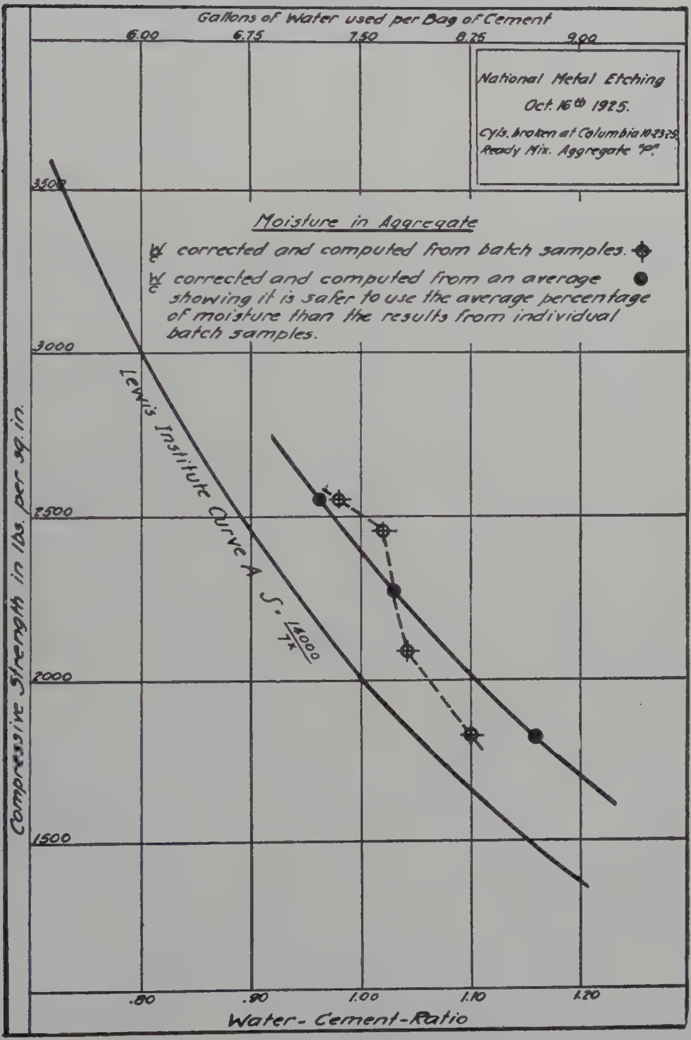


FIG. 6. — MOISTURE CONTENT OF AGGREGATE USED IN NATIONAL METAL ETCHING JOB

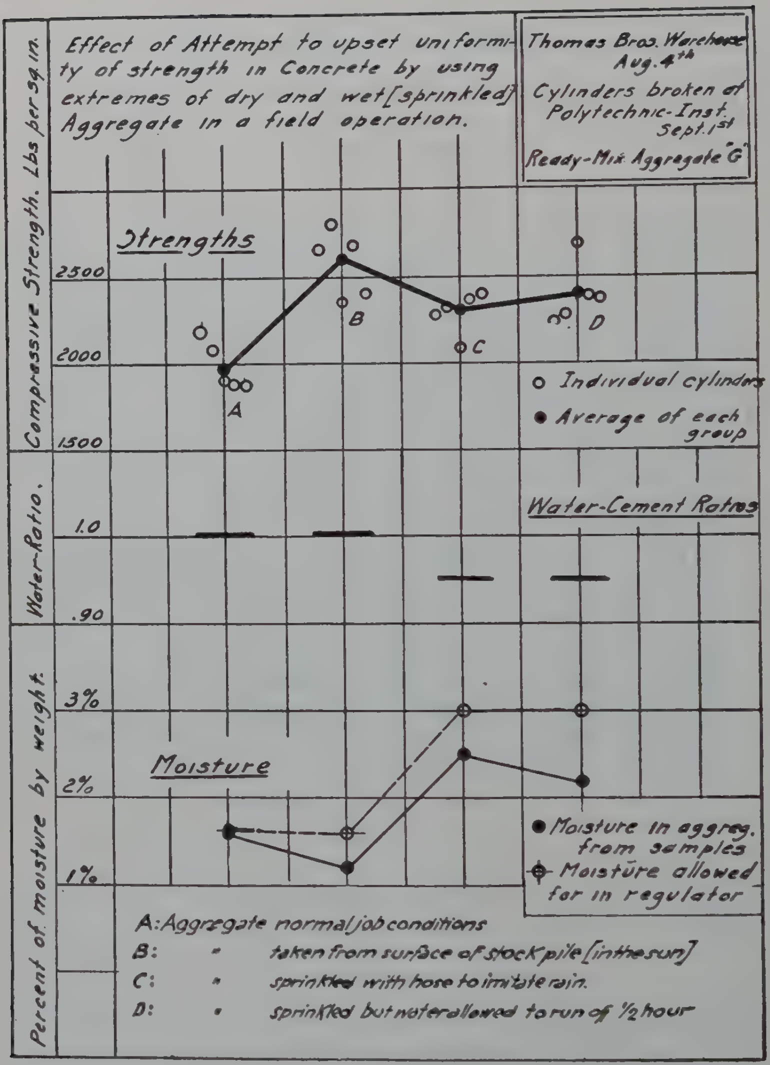


Fig. 7. — Results of Tests made on Thomas Bros. Warehouse Job

the good old pail or water barrel substituted. When we realize, as above stated, that three quarts of water in a two-bag batch changes the strength of resulting concrete 200 lbs. per sq. in., it is small wonder that under the old methods we needed large factors of safety and demanded very rich concrete in order to be on the safe side. It appears, however, that we are approaching the day when this variable can be overcome in a simple way on every job. The "inundator" is a step in the right direction. The device described below is believed to be a simpler and better method.

Fifth is the *quantity of cement* added to each batch. This is a much more serious variable than commonly known or considered. It should be noted that the following variations may take place in *every* batch.

(*a*) *Change in Weight of Cement Bags.* — Table 3, included in this article, shows weights of 100 bags of cement weighed consecutively from the stock pile on a recent job, just as they would run going into the mixer. The weights show a variation of as much as 10 lbs. from high to low. The average is in exact accordance with the weight commonly assumed (94 lbs. net). The variation of 5 lbs. in a one-bag batch will cause a change in strength of 400 lbs. per sq. in., as shown by the water-ratio curve. This factor must be considered if absolute control of strength of concrete is desired. This variation is probably caused by

TABLE 3. — WEIGHTS OF 100 CEMENT BAGS IN POUNDS; WEIGHED CONSECUTIVELY ON APRIL 20, 1926, AS RUN OF STOCK PILE, MACY JOB, LONG ISLAND CITY, N. Y.

97	94	94	97	94	94	96	95	98	100
93	96	97	94	99	94	94	94	93	90
93	93	93	97	97	95	91	93	101	98
94	98	91	96	94	95	96	94	98	96
95	97	98	95	95	94	93	97	93	99
97	98	98	97	95	95	95	98	92	96
95	97	93	95	94	95	94	93	93	92
98	93	94	92	95	94	96	95	94	100
96	94	93	95	93	93	93	98	93	92
98	99	95	95	91	98	97	95	97	95

Greatest variation between any four bags taken consecutively	10 lbs.
Greatest variation between any two bags	11 lbs.
Average weight per bag	95 lbs.
Average weight of empty sack	1 lb.

the men at the cement mills filling the bags on a piece-work basis. There should be an adjustment for this variable in every batch of concrete, if possible.

(*b*) *Change Due to Shaking Bags.* — Notice should be taken of the manner in which cement is shaken out of the bags on a job. Often as much as 2 or 3 lbs. of cement is left in the bag when improperly shaken. This variable must be considered if uniformly strong concrete is wanted, as 2 lbs. of cement in a one-bag batch will affect the strength of concrete (if water is kept the same) to the amount of 160 lbs. per sq. in.

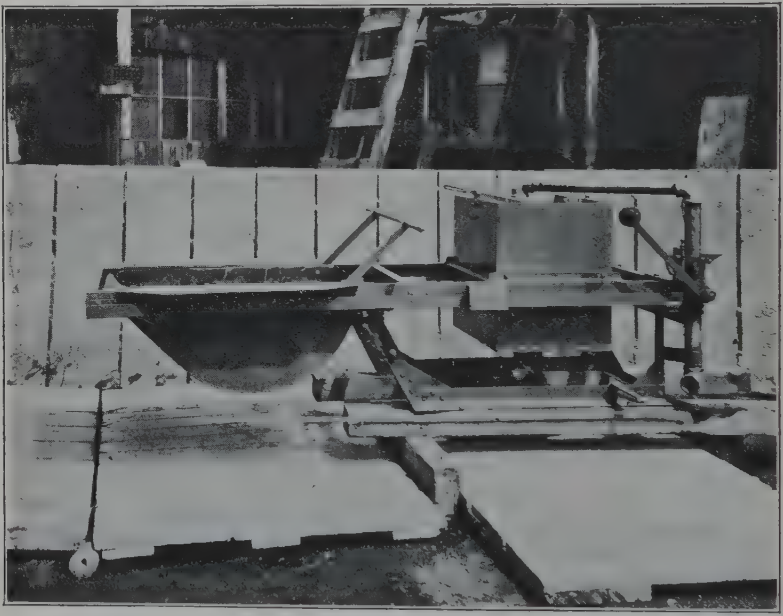


FIG. 8. — AHLERS CONCRETE STRENGTH REGULATOR

(*c*) *Lumps in Cement Bags.* — There are often lumps in cement stored on a job. When these lumps are thrown aside and no corresponding corrections made in the amount of water, a serious change takes place in the expected strength of the concrete in the batch. This variable should be controlled in some manner.

(*d*) *Torn Bags.* — Many torn bags come on the mixer platform and cement is also spilled around on the mixer platform as well as in the storage shed. If this is not compensated for, other changes in the strength of the concrete will be occasioned thereby.

There is, therefore, a great necessity for refinement in controlling these variables. All these are very serious, and the control of them may seem to present unsurmountable difficulties. However, they can all be overcome by a very simple arrangement on the job.

It will be noted that the refinement really needed is the control of the water-cement ratio itself, or the factor $\frac{W}{C}$. If this can be controlled on a laboratory basis on the large scale required at a mixer plant, resulting uniform concrete should be obtained.

The necessity, therefore, of an easily used laboratory tool is apparent. Such a tool or device, shown on Figs. 3 and 8, is simple in operation, has no moving parts, and cannot get out of order. The diagram showing the application of this device demonstrates further the exactness of the working of the water-ratio control on the job.

JOB CONSTANT

As previously stated, every aggregate has its own strength value when combined with a given brand of cement, regardless of how much or how little of the aggregate is used as long as we fix the ratio of water to cement. To establish this "job constant," using a "regulator," it is only necessary to run, early in the job, many batches of water and cement at the fixed ratio and then combine the mixture with any desirable quantity of coarse and fine aggregate to give the workability the contractor and engineer wish to secure. Note on diagram that this job constant is considered best established at or near the water-cement ratio of "one," as this is commonly assumed to give about 2,000 lbs. per sq. in. We find, however, that it usually gives a higher strength than 2,000 lbs. because we use clean, sharp sand. It may give a lower strength if the aggregate is poor in quality and the cement not of the highest standard. This job constant must be established, however, and when once established it is a very simple thing to go higher and lower in the scale of strength to get exactly the strength desired for the particular part of the structure.

ELIMINATION OF ALL VARIABLES

As may be seen from this diagram, by a simple sliding of a weight, the amount of moisture that is present in the aggregate (which is easily computed) can be compensated for directly on the balance, omitting an amount of water equal to that which is already in the aggregate.

As stated above, and confirmed by other investigations, the percentage of moisture runs very uniform throughout any one day's operation and under any given weather condition.

Comparison of Results under (a) Old Method, (b) Job System of Exact Laboratory Method, (c) Construction of Portland Cement Association Building, Chicago

Let us now compare the results in strength under such a basis of control with those obtained by other means. Note in the diagrams of curves attached, marked Job 195, how nearly the strength runs to a

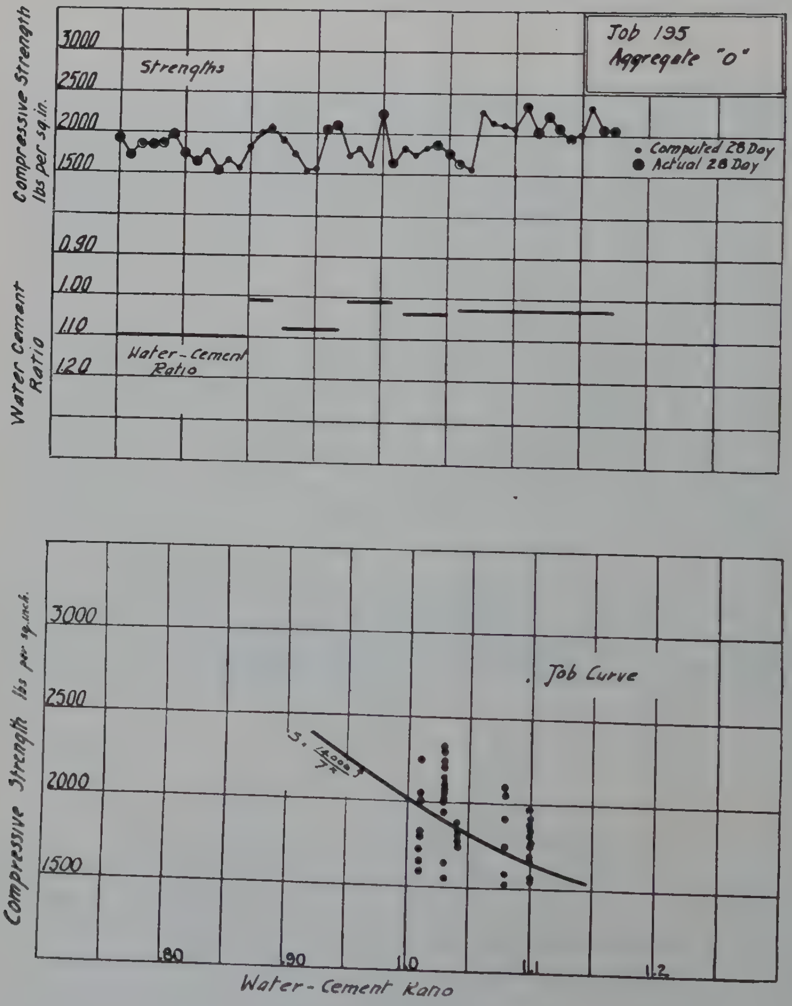


FIG. 9. — JOB 195

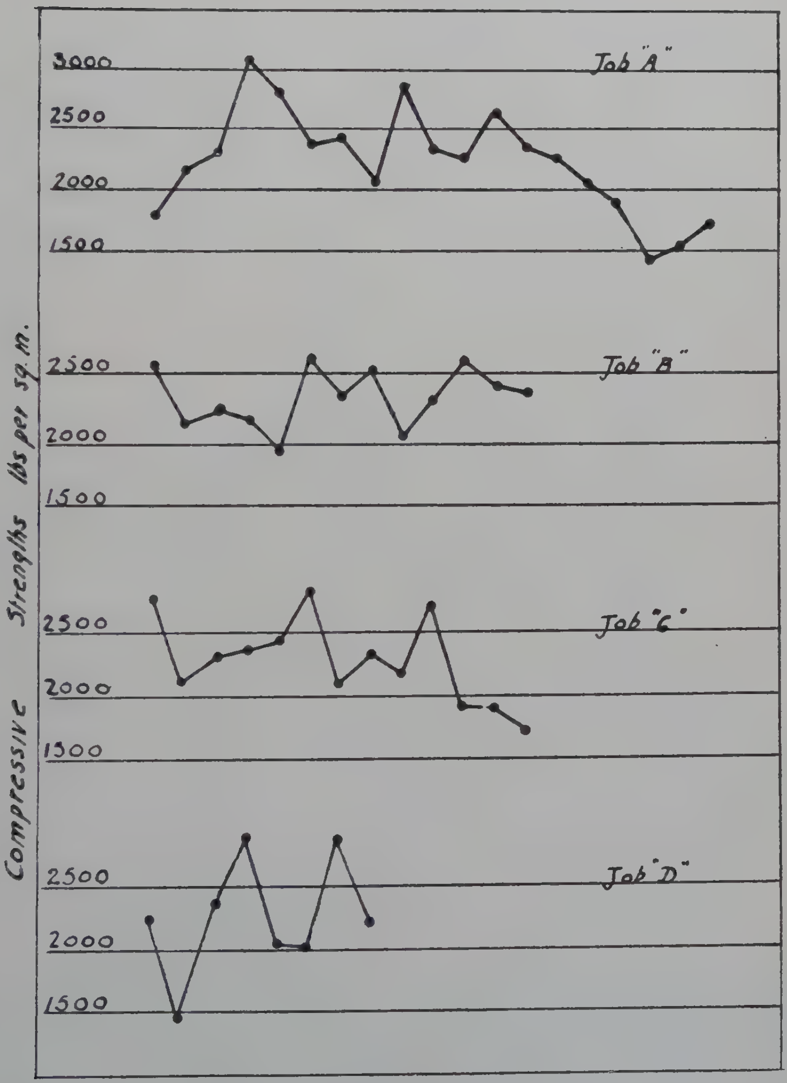


FIG. 10. — RESULTS OF TESTS BY JOHN G. AHLERS AND STANTON WALKER

Reported to American Concrete Institute in 1923 predetermined line, following actually parallel to the water-cement ratio as adjusted on the Regulator.

We should look for a moment at the curves that were plotted from job tests made in 1923 under the old system of controlling concrete, and note the variation in strength, ranging from 1,500 lbs. to above 3,000 lbs. We should also note the line of strengths plotted directly from Table 4 of a paper by McMillan & Walker on the control of concrete on the Portland Cement Association Building built in Chicago last year. This was controlled by the water-cement ratio, but there is no indication of a high degree of uniformity. This lack of uniformity is evidently caused by not carefully controlling the variables which we have discussed. Where these are not properly allowed for, we may expect to find an excessive strength and a consequent waste of cement and other material. It is entirely within the limits of expectation, however, to secure concrete that will vary in strength not much more than 100 lbs. either way from the strength required in any specification.

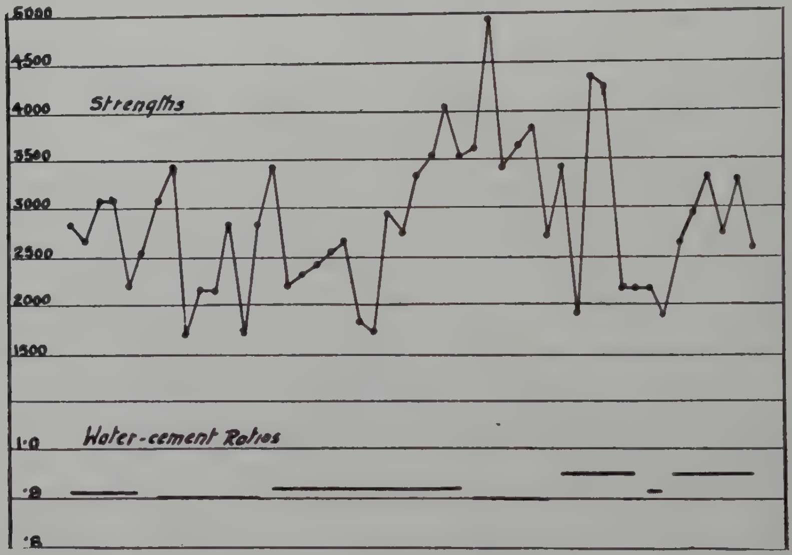


FIG. 11. — TESTS ON PORTLAND CEMENT ASSOCIATION BUILDING, CHICAGO

Results taken from Table 4 of a paper by F. R. McMillan and Stanton Walker, presented before American Concrete Institute, Feb. 4, 1926

It is proper to state, too, that of any group of cylinders, if any exceptional cylinder runs low it is apt to be caused by an inherent fault in the cylinder itself and not the result of low strength in the concrete. For this purpose note the comparison of core borings and cylinders taken from the job (Table 4), inserted from a paper by Mattimore from "Engineering News-Record." This table shows the higher strengths that are obtained in the concrete in the structure than in the concrete cylinders both for averages and maximums. Therefore the rule that cylinders running more than 15 per cent below the average should be rejected and a new average computed, is a very safe one to follow; also it is to be noted that there is considerable safeguard in using the equation $S_{28}=S_7+30\sqrt{S_7}$.

TABLE 4. — COMPARISON BETWEEN CORE BORINGS AND MOLDED SPECIMENS

Taken from article by H. S. Mattimore, Engineering News-Record, Jan. 12, 1922

	Molded Specimens at 28 Days	Computed Strength at 300 Days	Core Borings at 300 Days	Series No.
Minimum	2,211	3,320	3,980	2
Maximum	4,054	6,150	6,070	
Mean	3,095	4,680	4,545	
Minimum	2,115	3,200	3,860	3
Maximum	3,315	5,000	5,452	
Mean	2,788	4,220	4,706	
Minimum	2,229	3,370	4,185	4
Maximum	4,357	6,590	6,585	
Mean	3,368	5,100	5,288	

STRENGTH AS AN INDICATION OF GOOD CONCRETE

There is much discussion of the fact that strength may not be the only indication of good concrete, and I believe there is also a good deal of confusion of ideas on this point. But Professor Abrams has shown conclusively in his tests that strength is indicative of all good qualities in concrete, as follows (Bulletin 17, "Studies of Bond between Concrete and Steel," Lewis Institute, page 10):

> The factors which produced high compressive strengths also produced high bond resistance. Other tests have shown that the same statement applies in general to resistance to wear, modulus of elasticity, impermeability and resistance to destructive

agencies such as weather, sea and sulfate waters, etc. It is particularly striking that curves showing the relation between modulus of elasticity and compressive strength have a shape similar to Fig. 4. The significance of this intimate relation between bond and modulus of elasticity is not clear.

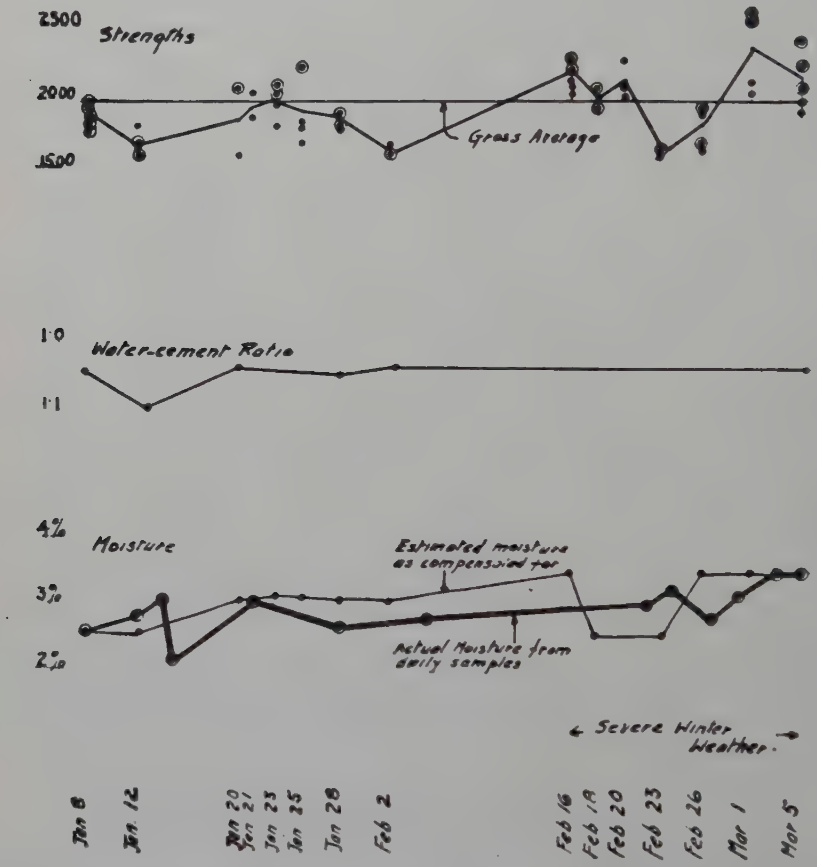


FIG. 12. — RESULTS OF TESTS. — GOODYEAR BUILDING, NEW YORK CITY

Furthermore, the Joint Committee on Concrete and Reinforced Concrete, in its proposed standard specification for concrete, bases all parts of design on factors of the ultimate strength in compression. This applies to bond, shear, modulus of elasticity, etc.

Data on Savings

On one of the jobs for which data are available (Lenox Laundry) there was an actual saving of $682.20 on 1,700 yds. of concrete. This is 40 cents a cubic yard actual saving, considering both aggregate and cement, and is no slight amount in any concrete job, no matter what its size.

On a larger scale job (a group of buildings aggregating 14,000 yds.) the actual saving in aggregate and cement amounted to $4,830. The total cost of test, including the services of two engineers, the breaking of cylinders, trucking, etc., was $2,700, leaving a *net* saving of $2,130, or almost 15 cents a cubic yard; the saving being about 35 cents and the cost of the test about 20 cents per cubic yard.

Conclusions and Appeal for Fair Trial

Finally, the statement that this method may not be 100 per cent perfect should be answered by saying, why wait until we have something 100 per cent? Supposing this method of control is only 95, 90 or 85 per cent perfect; it is better than anything we have had up to the present time, and it should be adopted and tried out by all who are aiming to make progress in securing better work and greater economy.

A special appeal is made to the engineers to give such a system of control as outlined a fair trial, and, in so far as possible, let the contractor use his own ideas and judgment as to the quantity, grading and proportioning of the aggregate. The engineer is urged to concentrate his attention on the factor that controls the strength, and that is the water-cement ratio. Let us adopt some system of absolute control of the ratio of water and cement entering into every batch and confine our efforts to watching this part of the production of the concrete. It is not the only system, but it has produced excellent results and saved money, for owners as well as for contractors.

As an incentive to the contractors for the use of this system, let the engineer experiment on at least 100 to 200 yds. of concrete early in the structure so as to obtain an idea of what ratio will give the desired strength of concrete in the work. Co-operate with the engineer in every way possible, and learn something about it, for by actual learning and handling, the contractor will soon find that he is going to save considerable money on the work. He will be able to bid lower, strip forms with more safety, and he will feel more certain of the concrete in the structure and will have the satisfaction of doing a better and safer job.

PROPOSED SPECIFICATION

For the use and information of those who may wish to write a specification for controlling and handling concrete on this basis, the following is quoted from "New Experiences in Concrete Control," American Concrete Institute, 1926.

Cement. — Cement shall be an approved brand of Portland Cement, and shall be tested in accordance with A. S. T. M. Standards for tension and compression. Must show a strength in compression of not less than 2,800 lbs. per sq. in. at 28 days.

Aggregates. — Aggregates to be composed of clean, hard, strong, durable uncoated particles free from injurious amounts of deleterious matter. Shall consist of fine and coarse, or a combination of same, such as will give a fineness modulus in combination varying not more than 10 per cent above or 15 per cent below the values given in Table III, Bulletin 1, of The Structural Materials Research Laboratory, "Design of Concrete Mixtures," or Bulletin of Portland Cement Association, "Design and Control of Concrete Mixtures."

Proportion. — The proportion of fine to coarse, and amount of each, will be left to the contractor, providing he complies with the other parts of this specification and produces a controlled, workable, well-mixed concrete.

Preliminary Tests. — The contractor will, under the direction and supervision of the engineer, make preliminary tests of the cement, water and aggregate in combination before starting actual concrete operations. From these preliminary tests a job constant will be established that will give the strength that is to be expected for a set definite water-cement ratio.

If these preliminary tests are not made in time, the proportions of cement to water and to coarse aggregate must be used as required by the engineer.

Moisture Determination. — Preliminary tests must be made by the contractor in conjunction with the engineer to determine the average percentage of moisture contained in the aggregate to be used for each batch, and when the preliminary tests are made the proper deduction for the amount of water present in the aggregate must be made to arrive at the water-cement ratio.

Preliminary Test Cylinders. — Preliminary test cylinders may also be made from bone-dry aggregate in small batches of definite ratio of water to cement, not less than 3 ratios and 7 cylinders of each, these cylinders to be broken at 7 and 28 days, and to govern along with the preliminary tests until further test specimens have been made. The water-cement ratio required to produce the strengths desired can then be computed from these and the preliminary tests.

Strengths. — The following strengths are desired:

Type 1: Non-bearing walls, curtain walls, slabs on fill, etc., 1,500 lbs. at 28 days.

Type 2: Structural members, beams, girders, slabs, etc., 2,800 lbs at 28 days.

Type 3: Columns, 2,500 lbs. at 28 days.

Control. — The volume of water per unit of cement to be used in the mixer must be controlled by some approved device regulating the water-cement ratio, with due allowance for moisture in the aggregate.

Supplementary Tests. — Early in the job additional concrete cylinders shall be made (not less than 7 for each 200 cu.yd. of concrete) until 1,000 yds. have been poured; then not less than 7 cylinders must be made for every 500 yds.; these cylinders to be cured and broken under A. S. T. M. Standard Specifications and under direction of the engineer.

Changes in Water-Cement Ratio. — The engineer shall have the power to change the ratio of water per bag of cement to conform with results of supplementary tests.

Moisture in Aggregate. — If desired by the engineer the contractor shall make two tests daily, to determine the average moisture content of the aggregate.

Proportions. — When concrete is controlled as above outlined the contractor may be permitted to use his judgment as to proportion of fine to coarse aggregate. It is recommended, however, that not less than one part of sand be used to two parts of coarse aggregate, nor more than equal amount of sand to the coarse.

Workability. — The workability can be judged by the slump, and the slump must be great enough to allow the concrete to give smooth surfaces when tamped against the forms, and uniform contact with reinforcement when properly rammed in place.

Engineers' Report. — Full data on all tests and cylinders made and broken to be furnished the engineer in charge.

Cement used. — The contractor shall estimate on using 1.30 bbl. of cement to each cubic yard of concrete in place, and shall state the amount of barrels estimated for the total job. If less cement is used on the total job he shall give a credit of one-half of the amount saved. If more cement is used by direction of the engineer this will be paid for at cost.

THE ART OF MAKING GOOD CONCRETE

By Edward S. Larned *

(Presented before the Affiliated Technical Societies of Boston, April 21, 1926)

In considering the setting properties of Portland cement we must bear in mind that standard specifications have fixed certain definite limits for initial and final set, not less than 45 minutes for initial, or over 10 hours for final. This of course is a generous, wide range, considered in the light of past experience, and is a measure of toleration to the manufacturer rather than a construction requirement, except in so far as it guards against quick and erratic set. Each brand of Portland cement has a certain individuality in its physical properties, including set, depending upon the materials used, the raw mix, the uniformity of the mix, the fineness of preliminary grinding, kiln temperature, and final grinding of the finished product, with set control by the use of a proper amount of retarder.

In a normal Portland cement, of any brand, increased fineness means quicker set and hardening. The standard laboratory determination of set, by either the Vicat or Gillmore needle method, is made on neat cement paste of normal consistency, which means that when rolled between the hands into a ball and dropped from a height of 20 inches, the cement paste will retain its shape, only slightly flattening, without cracking.

On a cement paste of this consistency, then, are the determinations for set made; in the case of the Vicat needle a definite degree of penetration for the initial and no penetration for the final set, and with the Gillmore needles (light and heavy), no penetration for initial and final set, measured in minutes from time of moulding.

This test serves the purpose of the specifications, but the results under practical construction conditions are of more immediate concern. We cannot use cement of the above-described normal consistency in concrete mixtures.

What, then, influences the set or rate of hardening of concrete? First, and under all conditions, the quantity of water used, assuming

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also, of course, that the water is pure and clean. Temperature of the air, water, sand and coarse aggregate also exerts a marked influence on the set and rate of hardening; low temperatures retard and high temperatures accelerate this action. The combination of excess water in the mix and low temperature has a most serious retarding influence and within certain extreme limits may be destructive.

Exposure conditions also play a part in the rate of set and hardening. Wet clay contact in foundations and walls retards this action, and it has been my observation that metal forms retard set rather more than wood forms, but this is only comparative.

In Portland cement of present composition a quick laboratory set is generally an indication of weakness or low strength. By quick, I mean an initial set under 45 minutes, approaching "flash." Normal cements of average fineness from the Pennsylvania region show an initial set in from two to three hours, approximately, and a final set in from four to seven hours, approximately.

Some years ago I made a series of tests to show the influence of water on the set and strength of Portland and natural cements, and will quote from my report then made:

> In the case of a well-known Pennsylvania brand, of normal quality, an increase of 4 per cent (by weight) in the mixing water (from 20 to 24) increased the time of initial and final set 230 per cent. That increase in water was equivalent to less than 2 quarts per sack of cement, and the resulting consistency was much stiffer than commonly observed in concrete operations.

Under temperature conditions above 50° F., slow setting and hardening of concrete may be caused by quick-setting cement, excess water and/or poor sand. All cements (Portland) do not react the same under the influence of excess water; some are quicker to recover than others. This can only be determined by trial, and I believe this a profitable field for research.

In testing sand to determine its suitability for concrete or mortar I believe it is wrong to proportion the sand and cement by weight and to use normal (laboratory) consistency.

Since we have come to call 94 lbs. of cement a cubic foot, let that stand until changed to meet fineness variations, but reduce the sand to exact weight — volumetric conditions for each sand — and then test in the same ratio proposed for use, with a consistency closely approximating the required conditions for the work to be done.

If it is desired to determine the relative strength of sands per unit measure of cement, the volumes of sands should be equal, and the volume is directly influenced by the relative specific gravity, percentage of voids, and moisture content.

The strength of concrete is primarily a question of voids in the mix (air and water voids). Considered separately the sand and coarse aggregate, gravel or crushed rock, if sound and undecomposed, are both stronger than the cement, but they lack the required cohesive qualities, so cement is added as a binder.

Reduced to the simplest terms, enough cement must be added to fill the voids in the sand and coat the sand particles, and enough of this mixture, or the mortar, must be used to fill the voids in the gravel or stone.

In practical operations an exact balance cannot be maintained, so it is necessary to provide a factor of safety in the proportions used to account for the variations in the sand and stone voids.

Strength considered, under working conditions, the cement void ratio in the mortar must be maintained, and the required workability of the concrete is governed by the quantity, or the size, gradation and quantity, of the stone or gravel. A common fault in concrete operations is the use of too much coarse aggregate resulting in a harsh mix, which the practical man on the job seeks to correct by the addition of more water, which only serves to segregate the particles, prevent a uniform distribution of the cement, the only binding material present, and, of course, increase the voids, with resulting loss of strength.

Portland cement requires a certain amount of water for hydration. It will, however, *carry* and *retain* an appreciable quantity in excess of the requirements for hydration, but, when that limit is reached, any excess must be considered free water, and in this condition segregation of the cement particles set in under the law of the size and weight of particles.

I believe it is undisputed that Portland cement contains particles ranging in size from the effective colloidal material to the particles retained on the 200-mesh sieve, and the latter are inert as a binding material or cement glue, so it is of primary importance to prevent segregation of the cement particles.

It is pertinent at this juncture to consider another property in water, and that is, its surface tension. Free water in concrete is naturally attracted to surfaces of the fine and coarse aggregate and to the steel reinforcement. This action is progressive and accelerated by the settlement and compacting of the mass in the first few hours following placement of the concrete.

Therefore, with excess water present, the tendency is for the cement to drop away from the under side of the aggregate and the steel, the space being occupied by free water, which is a good void filler but not permanent, and totally lacking bonding qualities.

Mr. N. C. Johnson of New York has brought this out most clearly in his micro-photographic study of concretes, and his contribution to the literature on this subject is well worth reading.

A vast amount of research and testing has been done in this country, especially during the past fifteen years, and a wealth of valuable information has been collected and published for easy reference. Authorities are not agreed upon an exact basis of design of concrete mixes; nevertheless, the fundamentals are recognized, and it is only in the relative values of the factors that differences are found.

One thing, however, upon which all now agree is the importance of the water-cement ratio as affecting the strength of concrete.

The difficulty has been and is to translate the theory of design and control into practical field methods. It is often the case that a construction job is served with sand, gravel or broken stone from two or more sources of supply differing widely in quality of material and preparation, ranging from the small dry-process plant to the large wet-process operation. A uniform or standardized mix under such conditions is impossible. A 5-yard load of sand from either source will account for 10 cubic yards of concrete in place, and at the usual rate of progress on a fast-moving job this load of sand in the hoppers will be exhausted in from 10 to 30 minutes — not much time for adjustment of the common gauging apparatus for measurement of water, fine and coarse aggregate. This instance is cited merely to emphasize the importance of having a proper factor of safety in the cement-sand ratio, and some one on the job that knows good concrete when he sees it.

Much important work is being done, and will continue, where the water gauge is a bucket in the hands of a laborer, and the canal type wheelbarrow is the measure for sand and stone, unchanged for at least twenty-five years, and responsible for the widest variations in the mix. Why should we not demand a barrow that is designed as a gauge instead of merely a vehicle? I made this suggestion to the Concrete Institute more than fifteen years ago, urging that manufacturers be advised of the need.

For large operations the inundation system of measuring sand offers promise of uniform and reliable volume, and may be used to determine voids, — an important factor in fixing the cement ratio. A more reliable and elastic system of measuring water is needed, with automatic cut-off that can be adjusted for the required amount.

High Early Strength Concrete

I have been asked to say a word about how to get high early strength concrete.

First. — Select a high-grade cement of established reputation.

Second. — Select a sound, clean, well-graded sand, with not over 10 per cent passing the 50-mesh sieve, and free from dust.

Third. — Use as stiff a consistency as can be handled in the work; the strength is then directly proportional to the amount of cement used.

Fourth. — Mix thoroughly, not less than 1½ minutes after all materials are in the mixer — 5 minutes seem to give about the maximum strength. Prolonged mixing (2 to 5 minutes) will produce the desired consistency with somewhat less water.

Fifth. — Protect the concrete from the sun and wind and keep moist.

Sixth. — Keep the temperature of the concrete from falling below 60° F. Higher temperature, if moist, will accelerate the hardening.

Seventh. — The present-known admixtures, called accelerators, are of doubtful benefit; all cements do not respond to them alike. Advance tests should be made with the cement in use. Calcium chloride has been used with beneficial effect with some cements, and when so used about 2 per cent of this material to the weight of cement, or 2 pounds to the bag of cement, is recommended. The calcium chloride should be dissolved in water and used with the mixing water. This is most helpful in cold weather, but is not a protection against freezing, and all the usual precautions to protect plain concrete under similar conditions must be observed.

THE DESIGN AND CONTROL OF CONCRETE MIXES

By Walter C. Voss *

(Presented before the Affiliated Technical Societies of Boston, April 21, 1926)

It is quite improbable that any one present this evening has not heard of the phrases "Design and Control of Concrete Mixes" and "Strength Specifications." It has been the experience of the Field Engineers of the Portland Cement Association in a great many instances to encounter a cynical attitude toward the entire subject. This probably has had its origin in the superficial regard paid to laboratory methods and the incident conviction on the part of many that laboratory methods are far removed from field conditions. It will be my primary effort in this paper to dispel, if possible, this unfair prejudice which is not the fault so much of the theory itself, but lies in a lack of intelligent investigation of its practical import of the theory, and, to be sure, the theoretical way in which it, unfortunately, has often been presented.

With these things in mind, I wish to digress for a moment to clear up certain misapprehensions which exist from a historical point of view. This entire subject has been studied and experimented with for a period of at least twenty years. The first inkling we have of an attempt to solve the problem of making good concrete came with the *Feret theory*, which was essentially a study of sand and stone voids which was the direct forerunner of what is more commonly known as the *Void theory*, which, in the writer's mind, was and still is a good one to bear in mind. In simple phraseology this theory aimed to fill the voids of a coarse aggregate with fine aggregate or sand, and then to fill the voids in the required sand with cement. Running parallel with these investigations the *Surface Area theory* sought to base cement content upon the quantity of neat cement grout necessary to coat all of the particles of aggregate. Many exhaustive experiments were conducted along these lines by persons who published their results, and, what is more, men such as Mr. Edwards of the Maine State Highway Department, made exhaustive microscopic studies of the action of cement with the aggregates and more particularly with the water, which were never published. The speaker has had the unusual opportunity to see the results of some of these experiments, and is convinced that there still is much to recommend, at least, serious consideration of surface area, if not unqualified adoption.

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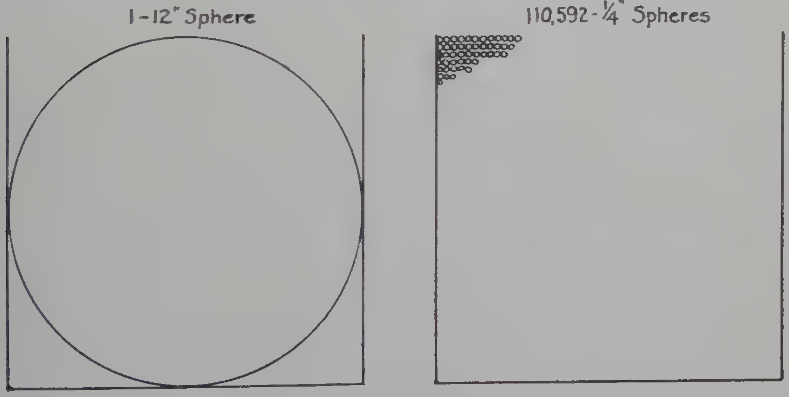
Messrs. Sanford Thompson and William B. Fuller conducted extensive tests on the Jerome Park Reservoir on the void theory, and coupled their investigations with sieve analyses, attempting to develop the Ideal Mix Curve, which for a long time was the basis of many schemes of concrete proportioning. This is a brief summary of the forerunning theories and experiments which within the last decade have resulted in the *Abrams' theory*, so-called, and the one which, at least at present, is the best we know of and the only one which takes definite cognizance of the water content. It is not at all improbable that these general ideas may be fused into a more comprehensive, logical and simple method of proportioning in the near future.

If you will pardon a personal opinion, I would like to say that I am a very keen exponent of "horse sense" in this matter, and I do not mean to discard or discourage laboratory investigations, but I would like to see these studies practically applied in the light of sound engineering judgment. Good concrete may be defined as a strong, dense, wear-resistant and economical combination of cement, sand, stone and water. I do not believe any one is interested in other more fundamental features.

Let us consider *strength* for a moment from the "horse sense" point of view. From its inception the design of every structure is predicated on strength. Every known coefficient for compression, diagonal tension, and shear is based upon an ultimate crushing strength. The engineer assumes at the start that the contractor will give him this strength. Building codes, the Joint Committee, and other practices and specifications lay down definite strengths for definite arbitrary mixes. We all agree that the cement causes the amalgamation of the inert aggregates, and we all appreciate that water is necessary to make it act. Water, then, is the vehicle which by chemical combination makes the dictionary definition of cement correct. As a verb, cement means "to hold firmly together," and as a noun, "substance which by hardening causes objects to adhere firmly." These definitions are good enough for me in their "simon-pure" form. If a cementing material has too much vehicle it is ineffective and weak; if it has too little vehicle it is inclined to become powdery and likewise ineffective. The best *glued joint* we know is one which is as thin as pressure can make it and in which the consistency of the glue is one which is just "tacky." You have watched an automobile tire man repair the inner tube of your tire. First of all he scrapes the spot to expose clean fresh rubber. He then applies the cement which has a volatile vehicle. You probably noted that he blew upon it. Why? To evaporate just enough vehicle to make the cement "tacky." If too "wet" the patch slips off, curls up and is useless. If too "dry," it simply drops off. But if just "tacky" it adheres at once and is better than any other part of the tube.

Now, this is exactly what should happen in concrete, with the very fortunate exception that the time elapsing between attachment and hardening is long enough to allow a great amount of working. This, then, being the case, I am of the opinion that Dr. Abrams is right in taking the stand that water is the all-important part in strength, and I repeat, it has been given the least consideration heretofore, and it was only the practical experience of the average contractor which resulted in structurally sound buildings, not to mention the unusual facility with which concrete increases in strength with age, which is evidence of the fact that cementation is going on long after a building is occupied and that laboratory initial and final set mean, practically, at least, nothing.



1728 cu.in.	VOLUME OF 12" CUBICAL BOX	1728 cu.in.
905 cu.in.	VOLUME OF SPHERES	905 cu.in.
47.5 %	VOIDS	47.5 %
453 sq.in.	SURFACE AREA OF SPHERES	21,600 sq.in.

FIG. 1.

Strength, then, is a function of the cementation of particles of fine and coarse aggregate, and the only thing you can cement is the surfaces; hence surface area comes in for its share of consideration. Certainly if there is no cement between two adjacent surfaces there will be no strength in that spot. The time of mix also plays an important part in the dissemination of this cementing fluid, so that all surfaces may be coated. The amount of cementing fluid is determined by the amount of cement, and this in turn by the area to be cemented. I would like to show the wide variance in this area by an illustration which any of you may check up. A 12-inch sphere will just fill a 12-inch cubical box. Its surface area is 453 square inches. If we filled this box with ¼-inch spheres we could get 110,592 such particles into the box. Their surface area, however, is 21,600 square inches. (Fig. 1.) Does your judgment tell you that the amount of finer particles requires the same amount of cement which the large particle does? I do not believe so. As cement plays an important rôle in the cost of concrete, you will readily appreciate the importance of keeping the percentages of "fines" down to a minimum. I will mention this, however, again in so far as it relates to density and workability.

Density! What a kaleidoscope of ideas, experiments, guesses and judgment that word implies! Yet it is extremely important in certain classes of concrete. Certainly all concrete which is exposed to the action of water and frost should be as dense as possible. Concrete which is veneered with other materials, and which, if exposed, is in a dry atmosphere, may be anything but dense, but still strong. Assuming the density which the former requires as an ideal, let us apply practical judgment to this characteristic of good concrete. Our very first premise is that we wish to have the entire mass so constructed that either a stone, a grain of sand, or a film of cement matrix occupies every possible space. This means fill the voids in the stone with sand, those in the sand with cement, and coat every particle in addition. If this is done the maximum *density* will be that of the parent rocks from which the aggregates descended. If these be porous they are responsible for lack of density. If they are dense, the making of the concrete is at fault should density be lacking. The next thing this word suggests to me is well-graded aggregates. Such materials will more readily result in density, require less cement and go into place with increased facility. I wish to use an example in this regard which I hope will prove my point. Referring again to our 12-inch sphere and 12-inch cubical box, we find that the volume of this sphere is about 905 cubic inches, leaving a void of 823 cubic inches. If we fill the box with the 110,592 ¼-inch spheres we find their volume is exactly 905 cubic inches with voids of 823 cubic inches again. (Fig. 1.) This shows that "all-one-size" aggregates are responsible for lack of density in a great many instances, and if strong, dense concrete is desired it can only be obtained at the expense of increased cement content.

Let us next consider the question of *wear*. This is based entirely upon thorough cementation and tough, hard sand and stone. Thorough cementation means a "tacky" matrix in proper amount. This may be obtained by not only gauging correctly the water used, but assuring one's self that this water is not allowed to dry out during this period in which it is necessary. It means proper curing. You are all agreed, I hope, that a batch of well-mixed almost perfect concrete may be completely ruined by rapid drying. This only means that mother nature has blown on your "tire patch" too long, doesn't it? There are other like considerations in wear, but I shall not discuss these further. The only thing I wish to impress here is that the owner of your building is the person or party who is primarily interested in density and wear-resistance. He is only indirectly interested in strength and economy which I shall discuss next.

Economy in concrete work, when adjudged from a practical point of view, means two things, — namely, a greater yield per barrel of cement, and sufficient workability so that no excessive costs shall be encountered in placing the concrete, in patching honeycomb, or in making other repairs after stripping. The *contractor is the one whose main interest centers in this feature.* It is into this part of the process of concreting that the Abrams' method throws the most violent bomb. The contractor conversant with the working of it finds that he may be able to obtain 1,500 lbs. concrete with a 1–5–9 mix. The contractor is interested on account of his pocketbook, especially if he has estimated the job in the old fashion. If he attempts to bid on the new basis he will be far below the nearest competitor on the old basis, but he must have a sympathetic engineer, architect and building department. They have specified an arbitrary 1–2½–5 mix, and I want to say that 1,600-pound concrete has been obtained consistently on mixes varying all the way from that approximate proportion to a 1–5–9.

The engineer should stick to his knitting. If the concrete tests 1,500 lbs. on the average it is what he wanted. Just because the Joint Committee or some other group of engineers have evolved an empirical rule of mixes as affecting strength it is no sign that a similar strength obtained with leaner mixes is not satisfactory. If I should invent a new material which was to be used structurally, and at its inception told you that I intended to use 1 part of my cement to 6 parts of "hunky dory" and 10 parts "pattootee" and 10 per cent of the "essence of stickum," and that this mix would give you a 2,000-lb. structural material, and did, the engineers would in all probability, if stated that way, specify it that way! Why the reticence to change concrete? Inertia is the only answer.

Having prefixed the practical application of "Design and Control" with these remarks, I want to give you some startling facts about the entire matter. If I should mix 6 gallons of water with 1 sack of cement I would get a neat cement grout. If I made 6 cylinders of this grout in the usual way they should average about 2,400 lbs. per square inch. If I made 6 cylinders each of the following mixes: 1–1–0, 1–1–1, 1–1½–2, 1–2–2, 1–2–3, 1–2½–4, 1–3–4, 1–4–4, 1–4–5, 1–4–6, 1–4–7, providing in all cases I had a smooth workable concrete, I would obtain average strengths of 2,400 lbs. in each case. This feature is well along the road to positive establishment, but I wish to emphasize the point here, that as I use increased amounts of sand and stone the human equation, which determines thorough dissemination of the matrix, proper working and uniform distribution of materials, increases also. As my quantities of aggregate increase, the fluidity is decreased; and as they are reduced, the fluidity is increased. At either extreme end of the scale dangers arise. When too fluid, laitance and segregation make such mixes undesirable from the standpoint of quality; when too stiff, costs mount up, honeycomb is almost a foregone conclusion, and proper distribution of matrix is a variable quantity. To place the thing in a simple way, the workability should vary between slumps of from, say, 2 to 6 inches, depending upon the condition surrounding the job. When 2-inch slumps are satisfactory the yield per barrel is materially increased; where 6-inch slumps are necessary the yield is necessarily reduced, the amount of water, the criterion for strength, being the same always. This being true the whole matter of concrete mixing is reduced to an extremely simple job practice. I will relate a typical actual case which we encountered recently.

I will give the dialogue which occurred at our suggestion between the president of a railroad company and a certain workman whom we will call Tony, who had been working for the railroad, mixing concrete and placing it, for about twenty-five years. The president, interested in the use of this theory on small jobs, opened the conversation with Tony in this way:

PRESIDENT: "Tony, do you know what good concrete looks like?"

TONY: "I think I do, Chief."

PRESIDENT: "You know, Tony, that I do not want any honeycomb and I do not want any soup."

TONY: "Yes, Chief."

PRESIDENT: "You know what honeycomb is, Tony, and you know when I say soup I mean an over-wet concrete?"

TONY: "Yes, sir."

PRESIDENT: "Now, on that culvert which you are going to build from our plans here, and which is out on the main line about 3½ miles, you are going to use about 150 barrels of cement, and I want you to take your gang and go out to that culvert and when your sand is dry I want you to use 6½ gallons of water for each sack of cement, and when your sand is damp I want you to use 6¼ gallons of water for each sack of cement, and when your sand is wet I want you to use 5¾ gallons of water for each sack of cement, and if I catch you using any more water than that on this job I am going to fire you, even if you have been working for the road twenty-five years. Now get out and build the culvert."

Tony looked at his chief in amazement, and after he got over his surprise he said, "What mix do you want me to use, Chief?"

PRESIDENT: "Tony, I didn't say a thing about mix. I said I didn't want any honeycomb and I didn't want any soup. Now you go out there and build that culvert."

Tony knew better than to dispute his chief, and he took his gang out to the culvert and started in, and after consulting with members of the gang a little bit he said, "Boys, we have always used 1–2–4 so we will try that." They mixed up a batch of 1–2–4 for the bottom part of the reinforced section of the culvert, which was pretty well down in the ground, and a narrow section, and Tony realized at once that the material would never go down there as stiff as it was. His very first inclination was to use some more water, but he said, "We won't use any more water because I will lose my job if we do." After he scratched his head for a number of minutes wondering what to do next, he said, "Well, boys, let's cut out 1 cu. ft. of gravel and 1 cu. ft. of sand and use the same water we used before with the bag of cement." They did. This was still a little stiff so they cut out another ½ cu. ft. of gravel and they had a nice workable concrete which went into that thin section and around all the reinforcement in perfect fashion. As they came up higher in the forms Tony said, "The boss didn't say anything about how much sand and stone I could use if I wanted to, so here goes," and as they approached the top portions of plain concrete they had reached a mixture of 1–4–7, conserving workability and fluid concrete which went into place beautifully.

All the time that this gang was working on this concrete the railroad president knew that he was getting about 2,400 lb.-concrete, and with the experience which his man Tony had as to the appearance of good concrete, and with the assurance that Tony's experience would produce a surface that was devoid of honeycomb and a concrete which would encase all the steel perfectly, he had a dense, strong, good-looking concrete without keeping a gang of inspectors on the job to enforce a rigid arbitrary mix specification.

The method used in the "Design and Control of Concrete Mixes" is merely a measure of the maximum mix we may use to produce the desired strength and workability. An adjustment of this mix may be made without hesitancy and without serious effect upon strength, by experiment with the first few mixes each day. As the quantities of aggregate are varied the workability is changed, and if too fluid it may be rendered stiffer by additions of sand or of both sand and stone, the water being constant. If a mix is rendered too stiff by the addition of sand and stone it may be made more workable by either reducing the amounts of aggregate or by adding both cement and water in the same water-cement ratio. The latter is often more economical and less troublesome, as the measuring devices for the sand and stone are often fixed at least each day if not for the duration of availability furnished by a definite stock pile or supplies.

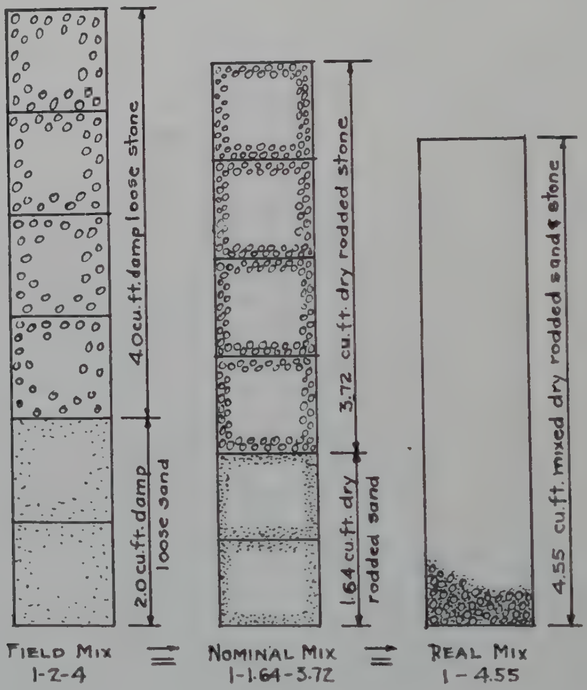

4.0 cu.ft. damp loose stone
2.0 cu.ft. damp loose sand
3.72 cu.ft. dry rodded stone
1.64 cu.ft. dry rodded sand
4.55 cu.ft. mixed dry rodded sand & stone
FIELD MIX 1-2-4
=
NOMINAL MIX 1-1.64-3.72
=
REAL MIX 1-4.55

FIG. 2.

I wish here to emphasize the wide variation which one encounters in the actual amount of sand used when measured damp and loose on the job. I would like to use some figures which I have had opportunity to compile in connection with the demonstration for the courses in "The Design and Control of Concrete Mixtures" which the Association has been conducting in this locality. Sand with about 3 per cent of moisture weighed about 84 lbs. per cu. ft. damp and loose. When dried and rodded into the measuring box it weighed 103 lbs. per cu. ft. In reality, therefore, 1 cu. ft. as measured on the job gave only 0.82 cu. ft. of sand in the mix. Similarly the stones averaged 98 lbs. per cu. ft. damp and loose and about 106 lbs. per cu. ft. dry and rodded. A cubic foot of stone as measured on the job in reality was only 0.93 of a cubic foot in the mix. If we started, then, with a 1–2–4 field mix based on damp,

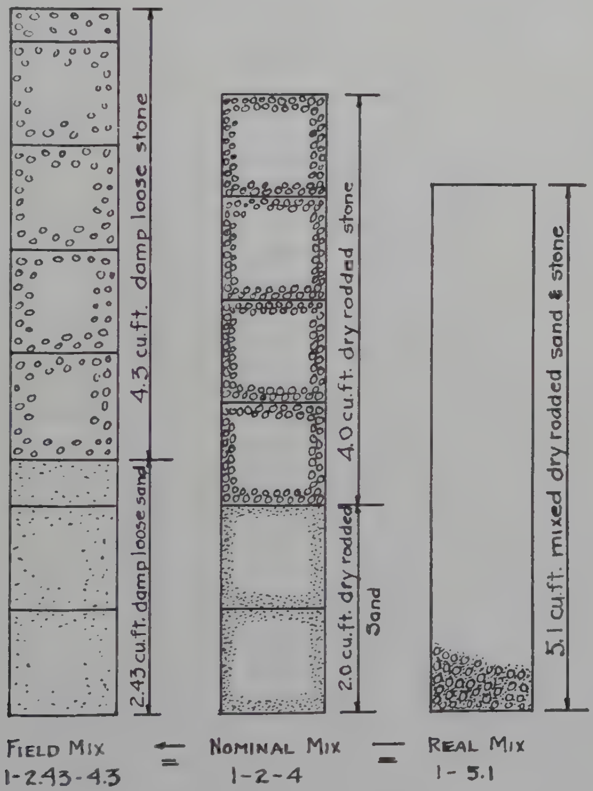

4.3 cu.ft. damp loose stone
2.43 cu.ft. damp loose sand
4.0 cu.ft. dry rodded stone
2.0 cu.ft. dry rodded Sand
5.1 cu.ft. mixed dry rodded sand & stone
FIELD MIX
1-2.43-4.3
←
=
NOMINAL MIX
1-2-4
=
REAL MIX
1-5.1

FIG. 3.

loose aggregate it would in reality be a 1–1.64–3.72 mix, and if we started with the premise that no engineer would object to a 1–2–4 mix on the basis of dry, tamped aggregate he should allow a 1–2.43–4.3 on the job with damp, loose sand and stone. (Figs. 2 and 3.) We have mentioned in all this data three mixes, — namely, the field mix, the nominal mix and the real mix. The first is as measured in the filed, — damp, loose and separate; the second is based on dry, tamped aggregate measured separately; and the third is based upon the dry, tamped, mixed fine and coarse aggregate. Let us analyze the arbitrary 1–2–4 field mix on the basis of these three steps. The 2 cu. ft. of sand, if dried and rodded, would be 1.64 cu. ft., and the gravel or stone 3.72 cu. ft. If we mixed these dry materials and then tamped them dry with our measuring box we would get approximately 4.6 cu. ft. This, then, would give us the number of cubic feet of concrete, excluding consideration of a small excess due to the cement, which 1 sack of cement would yield. If divided into 27 cu. ft. we would get 5.85 bags of cement per yard of concrete. (Fig. 2.) When one considers all these factors it is obvious that arbitrary mixes have some basis in fact, and that generally richer mixes do tend toward stronger concrete, but purely within the limits of the method of design and control as advocated by Abrams.

In conclusion I want to advocate a specification outline which can and has been used with a great deal of success. Specify your water to make your strength. Make allowance for damp and wet sand. Specify the maximum quantity of aggregate measured separately and loose which may be used per sack of cement. Allow the contractor to give you workable plastic concrete which will not honeycomb, and which is not harsh, not segregate, and which will completely and easily fill the forms. In cases where density is paramount make sure your sand is at least one-half that of your stone in volume, and I would advise a two to three relation as a minimum and add about 10 per cent more cement to assure sufficient matrix. Insist upon good mixing for a minimum of 1½ minutes after everything is in the mixer. Suppose we illustrate this for 2,000-lb. concrete subjected to water infiltration.

Not more than 6 parts sand and gravel measured separately and loose.

The gravel shall not be more than 2 times the volume of the sand.

The water used shall not exceed 6½ gallons when the sand is dry, 6¼ when damp, and 5¾ when wet. The mix of 1–2–4 used under ordinary conditions will probably be undersanded when the sand is damp, and I would advise, say, a 1–2½–3½ as the arbitrary mix which would meet the requirements.

Allowing 10 per cent more cement would make a 1.1–2.5–3.5 or a 1–2.26–3.18, say, 1–2¼–3¼.

For a 2,000-lb. structural concrete allow, say, 1 part of cement to 8 parts of sand and gravel measured separately and loose.

Not greater than twice the volume coarse to fine.

Same water consideration.

This will probably develop into a 1–3–5. If too harsh, a 1–3–4 might be tried. If too stiff and too harsh, 1–2½–4 may be what is necessary. This will yield as follows:

1–3–5: 5.8 cu. ft. — 4.7 sacks per yd.
1–3–4: 5.2 cu. ft. — 5.2 sacks per yd.
1–2½–4: 4.9 cu. ft. — 5.5 sacks per yd.

as against the arbitrary 1–2–4 yielding 4.6 cu. ft. requiring 5.9 sacks per yard.

OF GENERAL INTEREST

NEW JERSEY SEWAGE WORKS ASSOCIATION

Eleventh Annual Meeting Held on March 26, 1926 — Matters of Interest to Sanitary Engineers Discussed

At the request of the Chairman of the Sanitary Section, Mr. Almon L. Fales, of Metcalf & Eddy, Consulting Engineers, Boston, has made the following report of the Eleventh Annual Meeting of the New Jersey Sewage Works Association held at Trenton, New Jersey, March 26, 1926.

The New Jersey Sewage Works Association was started about ten years ago by a small group of sewage works operators in New Jersey interested in promoting mutual helpfulness. Important associations of sewage works managers have existed in England for many years, and those familiar with sewage works in this country recognize the need of such an association here. The New Jersey Sewage Works Association has met this need admirably. No state lines are drawn in its membership, which is now made up of those interested in sewage treatment from far and near. The Association holds annual meetings and usually publishes its proceedings promptly.

Instruction for Sewage Works Operators

At the recent meeting of the New Jersey Sewage Works Association, the Association endorsed a proposal for a two or three weeks' course for sewage works operators at Rutgers College in co-operation with the State Board of Health, as recommended by a Special Committee on the Improvement of the Status of Sewage Works Operators. The course would include lectures, laboratory work and inspection trips. There would be a nominal fee for those from within the state and a slight additional charge for those outside. The Association voted to promote legislation for the payment by municipalities of the expense of their sewage works operators taking the course.

Program of Annual Meeting

The program of the recent meeting included round-table discussions on: (1) Surcharging of Sanitary Sewers by Run-Off from Rain and Melting Snow and the Effect on the Treatment Plant; (2) Cleaning Sewer Lines; Necessity and Methods, and interesting papers and discussions on Sewage Sterilization, Sludge Drying and Sludge Digestion. In this report, reference will be made only to some of the important points brought out in these papers and discussions.

The Disinfection of Sewage Plant Effluents in New Jersey *

Mr. Daniels gave a practical demonstration of the operation of a chlorine apparatus for the disinfection of sewage. He stated that there are forty-six sewage treatment plants in the state where the effluent is chlorinated. The maximum amounts of chlorine, in parts per million, which have been found necessary for the different effluents in order to meet a standard of not over 100 B. Coli per cubic centimeter were as follows:

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* By Mr. P. N. Daniels, Senior Sanitary Engineer, New Jersey State Board of Health.

Imhoff or sedimentation tank effluent	20
Sprinkling filter effluent	18
Sand filter effluent	12

For the better effluents, smaller amounts were sufficient. In the case of one sand filter effluent, the amount of chlorine required was only 1 or 2 parts per million.

In the opinion of Mr. Daniels, the detention or contact period to be provided for after chlorination should be based on one-half hour at the average rate of flow. For two trickling filter plants, the New Jersey State Board of Health approved the application of chlorine just ahead of the secondary tanks. The chlorine treatment may be controlled by maintaining free chlorine in the effluent. In testing for free chlorine in sewage and turbid effluents, the starch-iodide test has been found to be more satisfactory than the ortho-tolidine test.

Air Drying of Sewage Sludge on Greenhouse-covered Sand Beds *

Glass-covered sludge beds were first tried at the sewage testing station in Cleveland in 1912 and 1913, and since that time sludge beds housed with greenhouse type of construction have been built at a number of places including Alliance, Canton and Marion, Ohio; Highland Park, Illinois; and Boonton, New Jersey. A careful study has been made of the operation of the glass-covered beds at Marion, and the results there and at Alliance have been compared with similar results for open sludge beds at Plainfield, New Jersey; Fitchburg, Massachusetts; and Schenectady, New York. Sludge was applied to the Marion beds twelve times during the year as compared with six or seven times at Fitchburg and Plainfield. Sludge applied to the Marion beds in winter was handled satisfactorily without artificial heat, and it is estimated that, if necessary, as many as twenty applications per year could be made.

It is estimated that the Marion sludge beds are capable of handling 0.6 cubic yard of sludge per square foot per year, or about three times as much as could be handled by open sludge beds. Assuming that 0.75 to 1.0 square foot per person is required for drying digested sludge on open beds, 0.25 to 0.33 square foot per person would suffice for glass-covered beds.

The cost of greenhouse-covered sludge beds is estimated at $2.60 per square foot as compared with $1 per square foot for open beds. The cost of operation and maintenance of covered sludge beds is no greater than for open beds, and perhaps less. It is, therefore, concluded that for northern climates, glass-covered sludge beds are not only more economical but much more advantageous in other respects than open sludge beds.

Practical Application of the Findings of the New Jersey Sewage Experiment Station.†

This paper commended the work of the New Jersey Sewage Experiment Station and outlined its practical findings in the investigations of sludge digestion. The entire discussion of sludge digestion will be reviewed further on.

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* By Floyd G. Browne, Superintendent of Sewage Treatment Works at Marion, Ohio, and Frank Woodbury Jones, Sanitary Chemist with George B. Gascoigne, Consulting Sanitary Engineer, Cleveland, Ohio.

† By Weston Gavett and Richard Gould, Members of the Research Committee of the New Jersey Sewage Works Association.

New Jersey Sewage Experiment Station

Closely related to the work of the New Jersey Sewage Works Association is the research of the New Jersey Sewage Experiment Station at New Brunswick, New Jersey. This research has been conducted under the joint auspices of the New Jersey Agricultural Experiment Stations and the New Jersey State Board of Health by Dr. Willem Rudolfs and his associates, with the co-operation of Mr. John R. Downes, Superintendent of the Joint Sewage Works at Plainfield, New Jersey, and Secretary of the New Jersey Sewage Works Association, and other sewage works superintendents. The research has included exhaustive studies of the flora and fauna of Imhoff tanks and trickling filters and experimental investigations of sludge digestion. The results of these investigations and studies have been published in bulletins issued by the New Jersey Sewage Experiment Stations. This research work has been supported in part by funds allotted to it by the Chemical Foundation. The New Jersey State Board of Health has withdrawn its financial support this year, but assurance has been given that the Chemical Foundation will continue its allotment.

Discussion of Sludge Digestion

One of the principal features of the recent meeting of the New Jersey Sewage Works Association was a discussion of sludge digestion. The findings of the New Jersey Sewage Experiment Station on this subject were presented by Dr. Rudolfs. Among these findings, some of the more important were as follows:

The kind and rate of sludge digestion and amount and composition of gas produced are dependent upon the hydrogen-ion concentration of the sludge, commonly expressed as the pH index which may be considered the true measure of acid or alkaline reaction, the neutral point for water being at pH 7.0, with lower values indicating increasing acidity and higher values increasing alkalinity.

At a certain reaction, maximum liquefaction of solids occurs with relatively low gas production accompanied by foul odors. At another reaction, equally rapid digestion takes place with relatively high gas production, but without offensive odors. The optimum pH for favorable sludge digestion lies between 7.3 and 7.6.

Natural sludge digestion passes first through an offensive acid stage, with relatively high carbon dioxide gas production, and under favorable conditions this is followed by an alkaline stage which neutralizes the acid condition and brings about inoffensive digestion with relatively high methane or marsh-gas production. At a favorable reaction, the gas will contain about 75 per cent methane.

The unsatisfactory acid digestion can be prevented by controlling the reaction or pH by the addition to the sludge of small amounts of lime. For the sludge at Plainfield, New Jersey, lime in the proportion of three or four pounds per million gallons of sewage was found to be sufficient to raise the pH to 7.3, and thereby reduce the time required for digestion about one-half. Mr. Downes confirmed the statement that with the pH maintained between 7.3 and 7.6, foaming will not occur in the Imhoff tanks. If too much lime is added, digestion does not proceed satisfactorily. At pH 8.6, it was found that there was an actual increase in the solid matter of the sludge on digestion.

By increasing the temperature of the sludge, the rate of digestion is greatly increased up to 85°F. Above this temperature, the rate of gas production decreases. At a certain reaction, heating the sludge from 60° to 85° results in rapid liquefaction of the sewage solids, but causes no increase in gas production. At another reaction, similar heating of the sludge brings about equally rapid digestion of sewage solids and greatly increases gas production. By maintaining the optimum pH and optimum temperature together, the rate of gas production is tremendously increased, and the time required for sludge digestion is reduced from, say, six months to six weeks.

The number of bacteria do not necessarily increase with increasing temperature. The numbers may be actually reduced by producing the most favorable reaction and temperature, but their activity is greatly increased.

Speeding up sludge digestion tends to concentrate any offensive odors produced. These odors can be prevented by sufficient seeding with favorably digested or ripened sludge. To maintain favorable digestion, the solids in the fresh sludge added should not exceed 2 per cent per day of the solids in the favorably digesting sludge in the tank.

A well-digested or ripe sludge cannot be told by the appearance or odor. Sludge having a black color may be in an early stage of digestion and offensive in odor. Odor may be practically absent in undigested sludge from some cause; for example, lime added to fresh sludge may eliminate the odor for a time and an awful stench develop later. Neither can the degree of flocculence of the sludge be relied upon to indicate its character. The percentage of ash alone or in combination with the appearance and odor is not conclusive evidence unless the original ash content of the sludge is known. The same is true of the alkalinity which varies with the percentages of solids in the sludge.

The extent or stage of sludge digestion depends upon: (1) kind of digestion taking place, — the flora and possibly the fauna of the sludge, and (2) state of oxidation.

During uncontrolled digestion the biochemical oxygen demand of the sludge increases, reaching a maximum after about 12 weeks. The pH index likewise increases, reaching about the neutral point at the peak of the biochemical oxygen demand curve. There is then a sudden and rapid reduction in the oxygen demand, followed by a change in odor from offensive to tarry. There is a definite relation between the oxygen demand and the stability of the sludge. A ripe sludge should have a pH value higher than 7.0 and an oxygen demand in 24 hours at 20°C not more than 1,000 p.p.m. for each percentage of organic solids; for example, to be in satisfactory condition to be drawn, sludge having 10 per cent solids of which 50 per cent is organic, should have a 24-hour oxygen demand not exceeding 5,000 p.p.m. This relation may be expressed by the following formula:

$$\frac{\text{p.p.m. B.O.D. in 24 hrs. at } 20^\circ\text{C.}}{\%\ \text{Volatile solids}} < 1{,}000$$

Mr. H. G. Baity, Rockefeller Foundation Research scholar at the Harvard School of Engineering, described independent experiments on sludge digestion at different temperatures and at different pH reactions carried out by him during the past year or more. His results for similar experiments confirm the conclusions reached by Dr. Rudolfs. With a mixed sludge composed of two parts by weight of fresh sludge solids and one part by weight of digested Imhoff tank sludge solids, little or no digestion occurred at 11°C (46°F); at 37°C (98.6°F) digestion was complete in two to two and one-half months. The total ultimate gas production was 400 to 500 liters per kilogram of organic matter for all suitable temperatures. The bacteria count reached 35 to 45 millions per cubic centimeter, both on gelatine and on agar, and remained substantially constant throughout the digestion at all temperatures. With a favorable pH maintained, the rate of gas production was twelve times that without pH control.

Sanitary Section Visits Lynn Outfall Sewer

On Saturday afternoon, June 5, 1926, the annual summer excursion of the Section was held. This excursion included luncheon at Lynn, Massachusetts, followed by an inspection trip of the construction of the Lynn Outfall Sewer.

The party left Rowes' Wharf at 12.20 P.M. for Lynn. Immediately upon arrival lunch was served in the banquet room at Huntt's Grill. Following luncheon there were short talks by Edward F. Twomey, Resident Engineer for Morris Knowles, Inc., Consulting Engineers for the city of Lynn; by George H. Burrows, Project Engineer for Merritt, Chapman & Scott Corporation, Contractors; and by Morris Knowles. Mr. Twomey described the "Preliminary Engineering Work and Supervision of Construction" involved in planning the Lynn Outfall Sewer project, and Mr. Burrows described the construction methods by which the contractor was carrying out his work. Mr. Knowles spoke regarding the project in general.

Through the courtesy of the contractors the entire party was taken by boat to the site of operations. Aboard the pipe-laying lighter several sections of pipe were made up ready to be laid, and the party witnessed the laying of one section. From here the boat carried the party to a point where the pile driver was at work on the bents to support the sewer. These piles are being driven approximately to grade, after which the pile caps are being placed by divers.

From the pile-driving operations the party was taken to the contractor's docks and storage yard on the Saugus River, where there was an opportunity to see the methods of handling pipe and other material. The various parts of the work were explained in detail by both Mr. Twomey and Mr. Burrows.

The luncheon was attended by forty-six, and fifty-two were present to take the boat trip down the harbor.

The party returned to Lynn about 5.30 P.M.

Sesquicentennial, 1926

The Engineers' Club of Philadelphia has issued a very cordial invitation to the members of the Boston Society of Civil Engineers to make use of its facilities if they visit the Sesquicentennial. Any member desiring to take advantage of this kind offer, which includes guest privileges for ten days at the Club, is requested to notify the secretary of the Boston Society of Civil Engineers in order that he may be furnished the proper credentials.

Street Names

Engineers confronted with the problem of naming streets in sub-division work will be interested in an article by Francis J. Mulvihill which appeared in the April, 1926, number of *The Florida Engineer and Contractor*. In this paper, entitled "Street Names for Subdivisions," Mr. Mulvihill, a B. S. C. E. member who has had a broad experience in city planning and development work, discusses the question in an interesting manner and gives typical examples of names used and mental processes by which they are sometimes determined.

PROCEEDINGS OF THE SOCIETY

APPLICATIONS FOR MEMBERSHIP

[June 15, 1926]

The By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as references does not necessarily mean that such members endorse candidate.

For Admission

Brustin, Nathan, Malden, Mass. (Age 23, b. Odessa, Russia.) Graduate of Malden High School and at present a student at Northeastern University. Has been employed by A. F. Sargent, Whitman & Howard, and Kelsey Co. during work periods. Refers to H. B. Alvord, C. S. Ell, H. B. Hamparian, W. E. Nightingale, Stanley Szlanda.

Call, Irving H., Wollaston, Mass. (Age, nearly 21, b. Burlington, Mass.) After graduating from the Quincy High School worked for Bowen & Co., contractors. Since February, 1924, has been a student at Northeastern University, and employed, during work periods, by Ernest W. Branch, C.E., of Quincy. Refers to H. B. Alvord, R. C. Chapin, G. A. Haskins, J. W. Ingalls, Stanley Szlanda.

Campbell, Henry Bowers, Boston, Mass. (Age 35, b. Parishville, N. Y.) Graduate of Clarkson College of Technology, Potsdam, N. Y., with degree of B.S. in civil engineering. Entered U. S. Coast and Geodetic Survey in 1912, where he has done field and office work of triangulation, topographic and hydrographic surveys, 6 years as junior officer, 3 years as executive officer, 4½ years as commanding officer of vessels engaged in surveys (8 years in Alaska, 3½ years in the Philippines, 2 years on East and Gulf Coast), and at present is Inspector in charge of Boston Field Station. Refers to J. N. Ferguson, R. K. Hale, E. N. Hutchins.

Giblin, Thomas R., Boston, Mass. (Age 20, b. Boston, Mass.) Graduate of Mechanic Arts High School, now attending Northeastern University; on work periods with Charles J. Elliot, engineer and surveyor, of Boston. Refers to H. B. Alvord, H. S. Cleverdon, C. S. Ell, Hampar Hamparian, J. W. Ingalls, W. E. Nightingale.

Kalinsky, Joseph W., Roxbury, Mass. (Age 21, b. Lomza, Russia.) Came to America in the summer of 1910. Attended grammar school in New York and Boston and in 1918 enrolled in the Technical Course at Boston English High. Entered Northeastern University in the fall of 1922 and employed by McClintock & Woodfall during work periods. Refers to Morris Bloom, H. B. Hamparian, G. A. Haskins, Frederick Mellor, Page Sanderson.

Moultrop, Leroy S., Shelton, Conn. (Age, 21 b. Shelton, Conn.) Entered Connecticut Aggie in the fall of 1923, and Northeastern University in February, 1924 where he is at present a student in the civil engineering department, and during work periods employed by the City Engineer of Ansonia, Conn. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Senior, Richard L., New Rochelle, N. Y. (Age 32, b. New York City.) From October, 1909, to April, 1912, with P. C. Hunter, on building construction as draftsman; from April to November, 1912, design and survey, city of New York, as draftsman on sewer and water supply; 1911–12 (evenings), course on strength of materials, Columbia University; 1912–19 (evenings), civil engineering course, Brooklyn Polytechnic Institute; November, 1912–December, 1917, chief draftsman and engineer, with J. S. Maher, architect and engineer; December, 1917–November, 1919, in charge of design of docks and piers in France, under Port Dept. of U. S. A.; December, 1919–May, 1926, design and superintendence of building construction; May, 1926, to date, with Jacob Gescheidt & Co., in charge of Boston office. Refers to M. J. Caddigan, L. H. Waters.

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NEW BOOKS

The library of the Society has recently received a copy of the third edition (1926) of Mills' "Materials of Construction." This reference book by the late Prof. Adelbert P. Mills is edited by Harrison W. Hayward, Professor of Materials, Massachusetts Institute of Technology, and published by John Wiley & Sons, Inc., New York. The new edition includes an increased treatment of the subject of alloy steel and alloys, and the chapters dealing with Portland cement, concrete and timber have been considerably revised. In order to insert important new material without unduly increasing the size of the book, certain matter, such as photographs, readily available from manufacturers, has been omitted in this edition.

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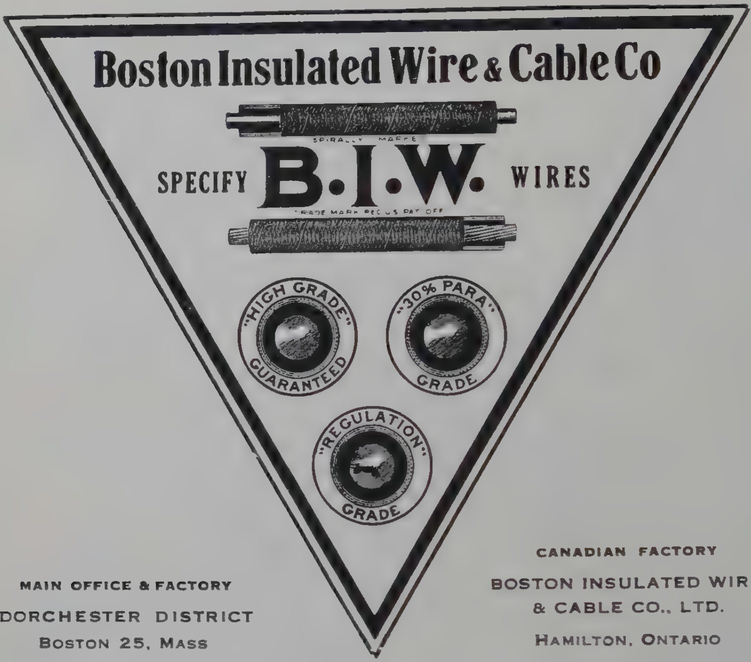

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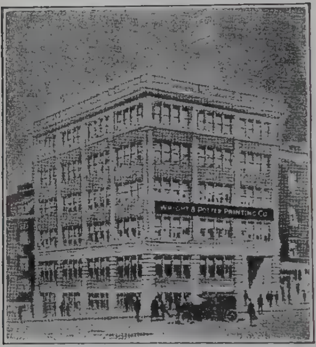

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